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Establishing a Peach Hedgerow Orchard

Max L. Allison • J.P. Overcash

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Establishing a Peach Hedgerow Orchard

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Foreword

Peach production in the United States exceeds that of all other countries except Italy. The Fruit Outlook and Situation, published by the U. S. Department of Agriculture Economics and Statistics Service, lists the total U.S. peach production in 1985 at 2.148 billion pounds (42.96 million 50-pound bushels) in 1985, and 2.28 billion pounds (45.6 million bushels) in 1986.

The southeastern states account for approximately one-fourth of this production. A renewed interest in commercial peach production in Mississippi began in the early 1980's and a high-density peach orchard was established at the Mississippi Agricultural and Forestry Experiment Station Pontotoc Ridge-Flatwoods Branch.

The current trend toward high density peach orchards (those with more than 100 trees per acre) began in the United States in the early 1960's. In conventional plantings, trees are usually spaced 20 feet apart in rows 20 feet apart (20 x 20 or approximately 100 trees per acre). High density orchards of smaller (dwarfed) trees have two or three times as many trees per acre. Success with high density apple orchards encouraged researchers and commercial peach growers to move to higher density orchards by planting trees closer together and reducing space between rows.

Much of the success with high density apple orchards is due to the availability of dwarfing rootstocks. The lack of suitable dwarfing rootstocks for peaches presented problems in higher density plantings because it proved difficult to control tree vigor and trees would overgrow their allotted space. Success, however, was achieved with the development of intensive management practices.

In this publication, the authors begin by summarizing recommendations for establishing a hedgerow peach orchard in Mississippi. This is followed by a review of early high density fruit production research, which provided the basis for the Mississippi high density peach production, reported in detail beginning on page 7.

Table of Contents

Foreword iii

Establishing a Peach Hedgerow Orchard
A Summary of Recommendations for Mississippi 1

Early High-Density Research 3

Preplant soil treatments 3
Nursery tree sizes 3
Tree spacings 3
Training systems 3
Summer pruning 5
Light penetration 5
Mineral nutrition 5
Irrigation 5
Pest control 6

Mississippi Peach Research

Materials and Methods 7
Results and Discussion 9
Tree sizes 9
Soil analyses 9
Leaf analyses 11
Fruit production 11

Summary and Conclusions 13
Conventional Trees Compared 13
Literature Cited 15

Establishing a Peach Hedgerow Orchard

A Summary of Recommendations for Mississippi

Site Selection

The location selected should allow cold winter air to freely drain away to avoid trapped cold air that could cause frost and/or freeze damage. Soil type should also be considered in the selection process. A soil with good internal water drainage may avoid tree root problems so trees will be healthy and bear good crops.

Soil Preparation

Test the soil for pH level and mineral content. Make necessary adjustments prior to planting. Adjust the soil pH to 6.5 or slightly higher. Subsoil, preferably to a 24-inch depth, to break any hardpan.

Irrigation

Irrigation is imperative. Install the system, whether it is trickle irrigation or overhead sprinklers, prior to planting and operate immediately after tree planting.

Establishment

Plant in early spring, in soil that is not too moist. Early planting allows the root system to become established before leaf bud break. Roots begin to grow at 50° F soil temperature.

Plant on a slight ridge to reduce the potential of root problems. If lime is needed, it should be added before final soil preparation. The tree row should be marked with a middle buster, then use a subsoil chisel in the bottom of the row to a depth of about 2 feet to allow the new tree roots to penetrate more easily.

Orient tree rows in a north-south direction. Tree spacing depends upon the level of management planned, the training system selected, and the size of equipment to be used. Size of tree blocks should be based on ease of cultural operations and the marketing system. Length of rows should not be excessive.

Training System

Trees in closely spaced training systems demand careful attention to pruning and require more pruning time than those conventionally spaced. A modified-leader fan spaced 12 x 14 feet or a trellis system spaced 10 x 14 feet is suggested.

Spacings between the rows should be at least 14 feet to accommodate a compact tractor, power sprayer, mowing equipment, and narrow trailers to haul the fruit and serve as a picking (and/or pruning) platform. Spacings within the row should be from 6 to 14 feet. More trees result in more early fruit. Early yields are usually correlated with tree numbers per acre. Hedgerow height can vary from 7 to 10 feet and yields often increase with additional tree height. Hedgerow width should ordinarily not exceed 3 feet for the permanent framework. Trees higher than 7 feet will require picking (and pruning) platforms (narrow trailers to fit middles), or ladders.

There are advantages for central leader trees, which may be trellised with a single wire at 6 feet. The trunk can be attached to the wire to prevent wind damage to both young and fruiting trees. Primary and secondary scaffold limbs can be developed to fill the hedgerow space. Another training system sometimes used is a modified central leader with large scaffold limbs being developed to fill hedgerow space with fruiting wood.

Evaluate the training system selected through actual experience before making large plantings. A trial planting of one-half acre is suggested. Keep good management records, including the amount of time spent for each operation. This information will be valuable for future decisions.

Fertilization

Adjust soil nutrients, such as P_2O_5 and K_2O, to recommended levels before planting, based on soil analyses and technical recommendations. Monitor soil minerals annually by collecting soil samples in late summer. If soil pH is below 6.5, add lime at recommended rates. Collect leaf samples annually in mid-August for tissue tests. Fertilizer needs will be indicated by foliar analysis and recommendations should be followed.

Nitrogen is the element most often needed. Split applications are preferred, particularly during the establishment period. Four monthly applications are suggested beginning one month after planting (April, May, June, and July) for the first two seasons. Irrigate to incorporate the fertilizer. In the third and subsequent seasons, two-thirds of the fertilizer should be applied in early spring (before growth begins) and the other third (after harvest) in late June, July, or early August.

Vegetation-free Band

Do not allow weeds and grass to compete with newly planted trees. A 2-foot weed-free band on either side of the tree row is recommended during the first year. Maintain a weed-free band to or slightly beyond the tree drip-line during succeeding years. Herbicides can be used to maintain the weed-free status. Cultivation cuts feeder roots and may injure the tree trunks.

Drive Middles

Fescue (Kentucky 31) is recommended for the sod middle. The grass selected should provide for traffic wear and should not easily creep into the weed-free band under the tree canopy. Sod is recommended over disking in order to allow cultural operations to be performed even during rainy weather.

Pest Control

An integrated pest management program should be followed. A standard spray schedule can be used as the alternative. Control recommendations can be obtained from the County Agricultural Extension Office.

Fruit Thinning

The amount of fruit to leave on the tree depends on the size and strength of the scaffold structure. Keep in mind that two or three mature peaches will weigh approximately one pound. Generally, 30-40 mature leaves are required to produce a marketable peach, depending on soil water supply and general cultural conditions.

Orchard Equipment

A low, narrow-profile tractor is ideal for hedgerow orchards. Orchard machinery, such as air-blast sprayers and flail chopper-mowers, usually require at least a 50-horsepower tractor to operate efficiently. For large operations, pneumatically operated pruners should be considered along with tree hedging equipment to mow the sides and top of hedges.

Marketing

A marketing program should be planned before the first tree is planted. There are several marketing systems which may be used, each of which has advantages for growers as well as the customer. These include:

(1) In "Pick Your Own" orchards, the customers are notified of the ripening periods, cultivars, and general availability (volume).

(2) In "Roadside Marketing," the grower picks fruit into consumer sized containers (packages) and has a salesperson wait on customers in a roadside stand.

(3) With "Wholesale Marketing," the fruit is packed in wholesale containers and sold to retailers in town or to packing houses for delivery to wholesale markets in distant cities.

Early High-Density Research

The basic recommendations for establishment and maintenance of high density orchards evolved from nearly two decades of research by many workers in a number of states and in other fruit-growing nations of the world.

A review of highlights of research prior to establishment of the Mississippi high density peach research orchard should help peach growers and research workers gain a better understanding of the establishment and management of orchards planted at densities of more than 100 trees per acre.

Preplant Soil Treatments

A 13-year study was made by Savage, Hayden, and Ward (41) in Georgia with 'Cornet' peach trees in old orchard sites subject to short peach tree life problems. Seventy-one percent of the trees in the pre-plant, subsoiled plots were still living while only 47 percent were living in the non-subsoiled plots. Subsoiling in row middles after planting was not beneficial. If trees were stunted during the first year in the orchard, they were not able to achieve optimum growth in subsequent years. The Georgia scientists also found a higher moisture content at the 12-inch depth during the growing season in the non-subsoiled plots.

Pre-plant recommendations (40, 41) included:

1. Subsoil to a depth of 18-24 inches to shatter compaction pans. Maximum shattering of the subsoil is achieved when the soil is relatively dry.
2. Fumigate soil that previously has grown peach trees, if a need is indicated by nematode assay. The soil temperature should be above 50°F at the 6 to 7-inch depth to achieve satisfactory results.
3. Liming the soil should adjust the pH to 6.5 and soil should have a favorable calcium (Ca) level in the top 12-16 inches for the southeastern United States. This is important because Ca moves only about 1 inch a year when applied to the soil surface and not incorporated.

Nursery Tree Sizes

Planting of nursery trees over 5 feet tall ordinarily is not recommended because tree vigor declines with the increased transplanting shock (5). Norton (36) stated that 1-year whips used in high density systems will require several years to catch up with well-grown, feathered nursery trees. Tall (6 feet) peach nursery trees planted in a hedgerow produced more fruit than short (2 feet tall) trees (1).

Tree Spacings

The planting distance selected for a hedgerow peach orchard should permit the bearing mantle to fill the row (hedge space) quickly, and provide early tree-root competition that would reduce vegetative growth and enhance yields (11).

Hartman and Hill (22) tested 'Redhaven' and 'Redskin' trees spaced 5, 7.5, 10, 15, and 20 feet apart in rows spaced 20 feet apart. Closer spacing resulted in tree competition for water and nutrients. Trunk circumference was less as spacing between trees was less. The closer spaced trees required more dormant pruning. Time required to prune trees spaced at 5 feet was two to three times that for trees with the 20-foot spacing. Yields in the third year were higher in plots with 5-foot spacing than in plots with standard 20-foot spacing.

Leuty and Pree (34) tested 'Cresthaven,' 'Olinda,' and 'Redskin' at three spacings (8 x 12 feet, 8 x 16 feet, and 14 x 20 feet) with three training systems (palmette, hedgerow, and standard open center). Moderately dense hedgerows increased accumulated yield 67 percent over the widest spaced rows during the first few years of the experiment. By the end of the ninth year, standard open center trees had out-yielded those in the other two systems. The most productive trees were the tallest and widest—height exerted the greatest effect on yield.

Chalmers, Mitchell, and van Heek (12) stated that "the growth rate or vigor of the vegetative portion of the top of a plant is directly correlated with the growth rate of the roots. One should be able to suppress the vigor of trees without dwarfing rootstocks if one can manipulate the soil factors that control the growth rate of the roots. When root growth of mature peach trees has been suppressed by age, the unused portion of their photosynthetic productivity is channeled into fruit growth."

Chalmers, Mitchell, and van Heek (12) spaced trees 3.3 feet within rows and 6½ feet or 13 feet between rows. Irrigation along with tree density was used to control root growth. The results of this experiment showed:

1. Higher tree densities result in root competition which affects fruit set and tree growth.
2. Trees pruned heavily in summer were not as productive as lightly pruned trees.
3. Trunk cross-sectional area was not reduced significantly in the closer spacings, but there was a trend in that direction.
4. Trees in the closer spaced plantings were taller than those at wider spacings, therefore light competition caused partial etiolation.
5. Trees irrigated least were the least etiolated.

Training Systems

Childers (14) believed that commercial growers desire a free-standing tree. The alternatives to free-standing trees are those supported by stakes or trellis. A trellis system in 1978 was reported to cost around $1,500 per acre. Cost of the stake system was slightly less. Most growers prefer to avoid expenses of support systems even though they have a number of advantages (7, 37, 38). Large trees can be planted to promoted early bearing, if supported. Trellis systems provide for support during ice storms, during strong winds, in periods of heavy crop loads, and provide a pattern for training the trees.

Childers (14) lists several advantages of smaller trees over standard sizes at maturity. Although his list was developed for apples, the points are valid for peaches if tree size can be controlled. Advantages listed by Childers for smaller trees are: **(1)** reduced pruning costs (50% or less); **(2)** less spray material per unit of fruit weight, and spray coverage is more thorough; **(3)** smaller trees permit use of smaller and less expensive orchard sprayers and other equipment; **(4)** laborers prefer smaller trees; **(5)** fruit quality is usually higher, therefore growers receive increased returns on investment earlier; **(6)** harvesting costs are half those required by picking from ladders; and **(7)** small trees are easier and less expensive to manage in nearly all operations.

Chalmers and van den Ende (11) presented five physiological and management criteria that they consider necessary for optimum yield: **(1)** tree design that fills the allotted space quickly, resulting in optimum land use; **(2)** uniform and controlled distribution of leaves and fruit to improve light interception and photosynthetic efficiency; **(3)** an order for branch and leaf array that diminishes light competition within and between trees to minimize the effects of crowding that usually results from high plant densities (especially with peach trees); **(4)** close planting to create root competition thereby reducing vegetative vigor, while increasing fruitfulness; and **(5)** high tree numbers per acre to provide high yields early in the life of the planting.

The Tatura trellis system (43) was developed with the view that it would meet these criteria. The rows were positioned in a north-south direction for maximum sunlight exposure. Tree spacing was 3.3 x 20 feet. Each tree had two scaffold limbs growing at right angles to the row-middles. Both scaffold limbs were trained at 60° - 70° from the horizontal so that the canopy formed a V-shape. Mature tree height was about 12 feet. The tip of the "V" canopy of one row was about 6½ feet from the tip of the "V" canopy of the next row. Summer pruning regulated canopy depth and shading.

Total yields were 2,700 bushels per acre for five growing seasons compared to 975 bushels per acre from commercial orchards with 122 trees per acre. Van den Ende and Chambers (43) believed that the Tatura trellis system would continue to yield at the maximum annual rate of 1,125 bushels per acre per year. The system did not show signs of over-crowding.

Orchard experiments (4) with high-tensile wire have shown trellises can serve as a management tool, particularly for pick-your-own operations. One acre of trellised orchard may have the same productivity as 2½ to 5 acres of free-standing trees. High-tensile wire, coupled with pressure-treated wood posts, may last 35 years or more and support more than one planting, depending upon the crop grown.

The M.I.A. (Murrumbidgee Irrigation Area, Yanco Research Station, New South Wales, Australia) system (9) uses an inverted "V." Fruit is produced on the outside and the system is readily suited to mechanization. The shape of this system is the reverse of the Tatura trellis. There are two rows of trees, one along each side trained toward the center so that the canopy is pyramid-shaped. This system overcomes the problem of removing interior pruning debris inherent to the interior portion of V-shaped designs.

Early high-density peach research in the United States was conducted by Hayden and Emerson (23) during the late 1960's and early 1970's. Their research used free-standing trees to avoid the costs of support structures. Training systems studied were:

1. High-density vase where scaffolds were tipped during the dormant season to strengthen them. Trees were sheared during the summer to limit tree size.
2. Modified-leader fan with a single central leader and lateral scaffolds extending in-the-row only.
3. Two-scaffold vase fan with both scaffolds developed in each direction in the row.
4. Pillar systems using a central leader with no scaffold branches. Small branches were tipped during the summer and fruited the second year. After fruiting the branches were pruned back nearly to the central leader.
5. Belgian-fence system with trees planted at a 45° angle. Tree tops were inclined in the row and vertical shoots developed from the inclined trunk.
6. Double Belgian-fence with two trees planted in the same hole but inclined in opposite directions in the row.
7. Standard open center trees were used as the control.

Results from this work (18) showed that yields were correlated directly to tree density. There was little effect due to tree training system except in the open center and vase-shaped systems where more severe pruning delayed fruit bud formation, thereby reducing yields in the first and second cropping years. Winter pruning was required for stiffening tree scaffolds to hold crop loads and summer shearing was necessary to contain growth to the allotted space. Harvesting costs for the hedgerow systems were reduced up to 60 percent over systems requiring ladders because the hedgerow systems used a moving wagon as a picking platform, when compared to systems requiring ladders.

Horton (26) designed an orchard for mechanized pruning, spraying, and harvesting without using a trellis. The canopy shape was a "Y" viewed from the end of the row.

New orchard designs should be considered carefully so they will be adaptable to new technology. Ideas to consider are: **(1)** worker preference for smaller trees, **(2)** smaller trees are convenient for pick-your-own operations,

(3) a planar surface is readily adaptable for machine pruning and harvesting, and (4) shallow canopies increase the effectiveness of pesticide applications as well as enhance sunlight penetration and photosynthesis.

Summer Pruning

Hayden and Emerson (24, 25) used summer pruning of peach trees to reduce tree vigor. Summer pruning was more dwarfing than winter pruning and promoted early fruit bud formation. Summer pruning promoted good light penetration, good fruit color, and uniformity of fruit maturity at harvest.

Christ (15) found the best time to prune (mow) peach trees, regardless of cultivar, was late July in New Jersey. Trees should not be mowed from the period 2 weeks before and through harvest to avoid shaking off fruit. Mow in early August if the cultivar ripened in late July. Mowing during these time periods removed the vigorous upright soft growth in the top of the tree, allowing sunlight penetration and enhanced fruiting wood quality.

Marini (35) reported summer pruning (selective cutting as opposed to mechanized shearing) plus winter pruning enhanced winter hardiness of fruit buds and reduced the amount of dormant pruning. This practice resulted in the largest yield and value per acre followed by dormant-pruned trees (no summer pruning); summer-mowed trees had the least yield.

Light Penetration

Several workers have reported that light distribution was adequate in the outside 10-20 inches of canopy but shading was very intense beyond that point (20, 29). They reported that hedging temporarily decreased shading in the fruiting zone, but regrowth caused additional internal shading due to increased leaf density. Dormant pruning was needed to open up the canopy to improve light distribution. The distance between trees in the row depends upon the level of management to be given. Generally, this distance should not exceed 10 to 14 feet. The minimum alley width should be determined by equipment to be used and the desired height of the hedge. The north-south row orientation was recommended for maximum light interception and minimum shading.

Beutel (8) found the lower fruitwood in hedgerow trees was not shaded out more than in conventional open center trees.

Mineral Nutrition

Nitrogen is the major nutrient used to control tree growth and fruiting. Other minerals are supplied mainly to prevent deficiencies (6, 13). Koch (32) stated that "calcium nitrate contains the lowest percentage of N and is the most expensive on a unit of N basis, but it does have some advantages. Soil pH will not be lowered to less than 6.0 and a substantial amount of Ca will be added to the soil with regular use."

Split or multiple applications of N provided for optimum growth. This is particularly important for immature trees. Brittain (10) stated that "in the Southeast, 45-90 pounds of N per acre annually are needed, with at least half as the nitrate form." It is known that "ammonium ions (NH_4), if present in the root zone, decrease the uptake of Ca and later interfere with the transport of Ca within the plant," (19). The amount of time required to change ammonium ions into nitrate ions is not resolved.

Trees deficient in Ca usually are not detected by foliar symptoms. Economic losses are associated with physiological disorders in fruit. Therefore, adequate Ca levels should be monitored carefully. A continuous supply of Ca to the roots is necessary along with adequate soil moisture.

Cummings (16) reported that soil pH below 5.6 resulted in poor tree growth, low fruit yield, and small fruit size. Tree longevity was enhanced when pH was maintained above 6.0 in addition to increased annual tree growth and fruit yield.

Childers (14) reported studies that showed that soil pH between 6.5-7.0 was desired in order to increase Ca availability. Jones (27) said yearly applications of lime, based upon soil analysis, were more desirable than large applications every third or fourth year, since the downward movement of lime was a slow process.

Micronutrients most often deficient in orchards are boron (B), iron (Fe), manganese (Mn), and zinc (Zn). Although soil analysis may serve as a guide to fertilization, Kenworthy (30) observed that the best assay of nutrient sufficiency is leaf analysis. Most leaf analyses are interpreted by a normal range. Shear and Faust (42) reviewed leaf-nutrient research results for peaches from throughout the United States and summarized the normal range for several elements. Toxicity ranges were not established.

Normal nutrient element ranges (42), as percentage of leaf dry weight, are: nitrogen (N) 2.5-4.0%; phosphorus (P) 0.14-0.40%; potassium (K) 1.5-2.5%; calcium (Ca) 1.5-2.0%; and magnesium (Mg) 0.25-0.60%. Normal element ranges expressed as parts per million of leaf dry weight are: manganese (Mn) 20-300 ppm; iron (Fe) 100-200 ppm; boron (B) 20-80 ppm; copper (Cu) 6-15 ppm; and zinc (Zn) 12-50 ppm.

Irrigation

Kenworthy (31) reported that 25 percent of the root system supplied with adequate water was sufficient to prevent moisture stress. Peach root growth was not confined to one side of the tree when water was only applied to one side. Peach roots were not made deeper or more shallow by irrigation methods. It was reported that 80 to 90 percent of the feeder roots are in the upper 12 inches of soil.

The edible portion of the peach fruit is approximately 87 percent water. It was estimated that 66 percent of the final fruit volume was attained during the last 30 days of growth. If fruit growth was slowed at any stage during its development, the final swell before ripening would not compensate for this loss. Proper irrigation would increase yields by approximately 25 percent due to increased fruit size (10).

Daniel (17) estimated that a large, mature peach tree requires 24 gallons of water per day. Brittain (10) stated that "water deficiency can reduce photosynthesis 40 percent before the leaves actually show wilting." He stated that 2 inches of water was required every 10 days from pit hardening through final swell, or a total water requirement for mature peach trees of 36 acre inches per year.

Trickle irrigation is an efficient method of applying water. It has been estimated to save 50 percent of actual water needs, with similar savings on energy costs.

Pest Control

Phillips and Weaver (39) reported that insects and mites were not a greater problem in high-density plantings than in conventionally spaced orchards. Hall (21) stated that less spray materials were required in the higher density plantings than in conventional orchards because: **(1)** the distance to adjacent rows was decreased, **(2)** the foliage was closer to the sprayer, **(3)** the rate of loss of air velocity and volume was reduced, **(4)** the efficiency of low-volume sprayers in relation to droplet deposition was enhanced, and **(5)** blow-through-and-wrap-around potentials were enhanced.

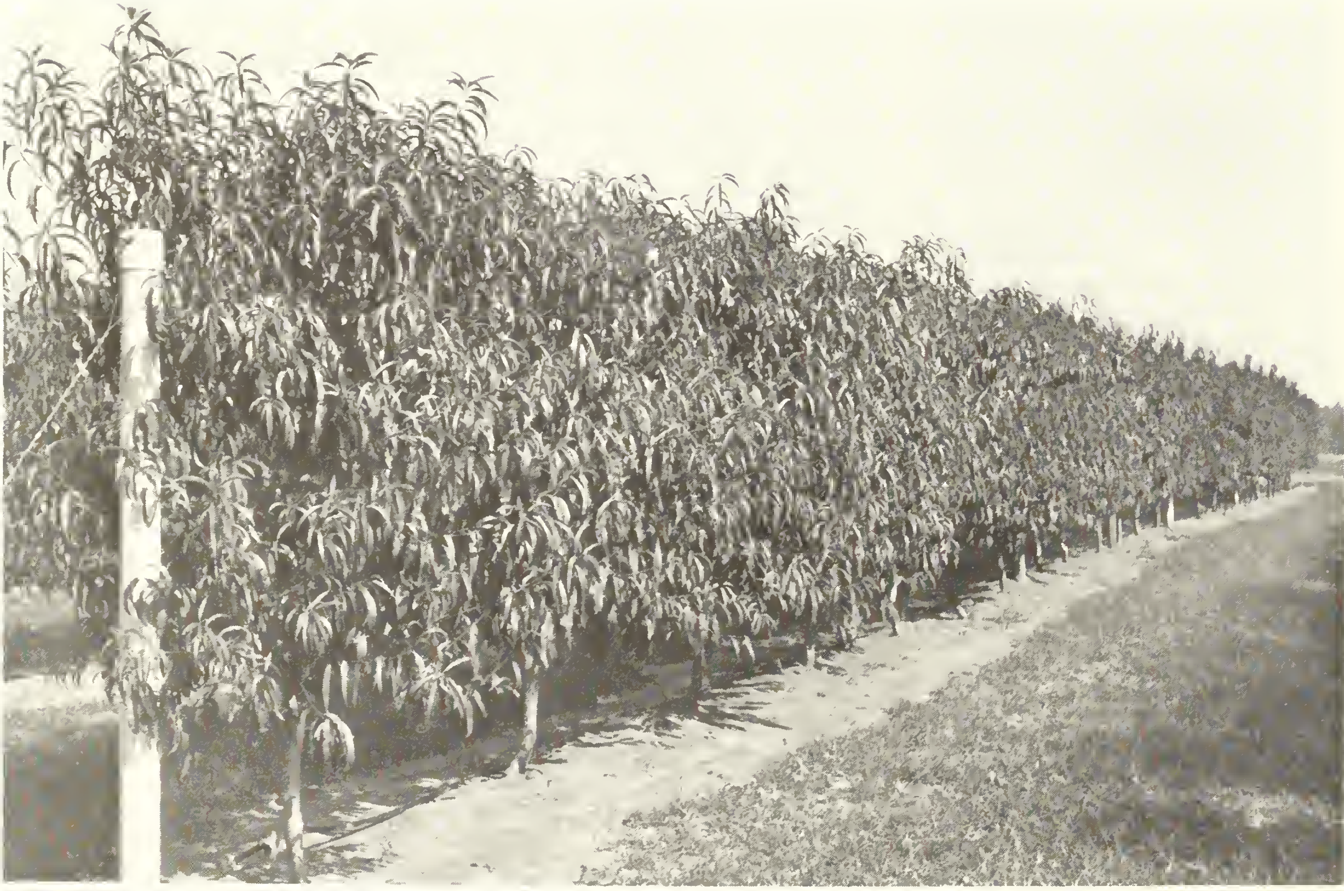


Figure 1. Peach hedgerow orchard at the MAFES Pontotoc Ridge-Flatwoods Branch Experiment Station in September 1981 (second year).

Mississippi Peach Research

A peach hedgerow orchard (Figure 1) was established at the Pontotoc Ridge-Flatwoods Branch of MAFES in Pontotoc County, Mississippi, April 10, 1980.

This experiment studied the effect of two tree training systems, initial tree heights, cultivars, fertilizer sources, and fertilizer rates on growth and precocity during the first 3 years.

Materials and Methods

A 2^4 factorial experiment was arranged in a split-split plot design (Table 1) with three-tree plots (Figure 2) and four replications (48 trees per replication) for two cultivars. Whole plots were trellis-trained or central-leader trained trees. Sub-plots were four fertilizers (two fertilizer types with two rates each). Sub-plots consisted of two nursery tree heights (16 sub-subplots each per replication). Cultivar treatments were analyzed using a randomized complete block analysis of variance. Mean separation was by Fisher's Protected LSD test.

The soil was an Atwood silt loam (fine-silty, mixed thermic Typic Palevdalfs), well-drained, with moderate permeability and high water-holding capacity (33).

Agricultural limestone (95% $CaCO_3$ equivalent) was broadcast at a rate of 3,000 pounds per acre and incorporated by disking in December 1979 to raise soil pH from 5.9 to 6.5. Soil P and K levels were adjusted to a medium range (70 pounds per acre of P and 240 pounds per acre of K) by adding 350 pounds of superphosphate and 250 pounds of muriate of potash. Nematode assays before and during the experiment indicated that soil fumigation was not needed.

Soil was prepared by using a parabolic subsoiler in two directions to a 16-inch depth and 24-inch spacing. A single middle breaker was used to open the tree-row furrow oriented north-south, and a single subsoil chisel was run down the furrow to a 24-inch depth. Rows then were closed by disking each side of the furrow to form a ridge 12 inches high.

Tree holes (24 inches in diameter, 20 inches deep) were bored 6 x 14 feet apart and trees were planted April 10, one week after forming the ridge. A soil berm was formed around each tree and filled with 3 gallons of water as needed, then leveled with soil when trickle irrigation was installed in May 1980. Trickle emitters supplied 1 gallon of water per tree per hour. Water was applied daily as needed (6 hours per application) May through August 1980-1982. Fifty centibars of soil suction measured at the 6-inch depth were used as the threshold to begin irrigation.

Fertilizers used were: Calcium nitrate—$Ca(NO_3)_2$ (15.5N-OP-OK), Sta-Green Super Nursery Mix (20N-2.6 P-4.4K) and seven micronutrients: (0.02% B, 0.05% Cu, 2.0% Fe, 0.05% Mn, 0.0005% Mo, 2.0% S and 0.05% Zn) produced by Sta-Green Plant Food Company (Sylacauga, AL).

Fertilizers were applied May 11 and 31, June 11, July 19 and 29, and August 5 and 16 in 1980 using a low rate of 4.2 ounces and a high rate of 8.5 ounces of elemental N per tree for both fertilizer types at each date. The low and high rates in 1981 were 8.5 ounces, and 17 ounces on June 1 and 15, July 14, and

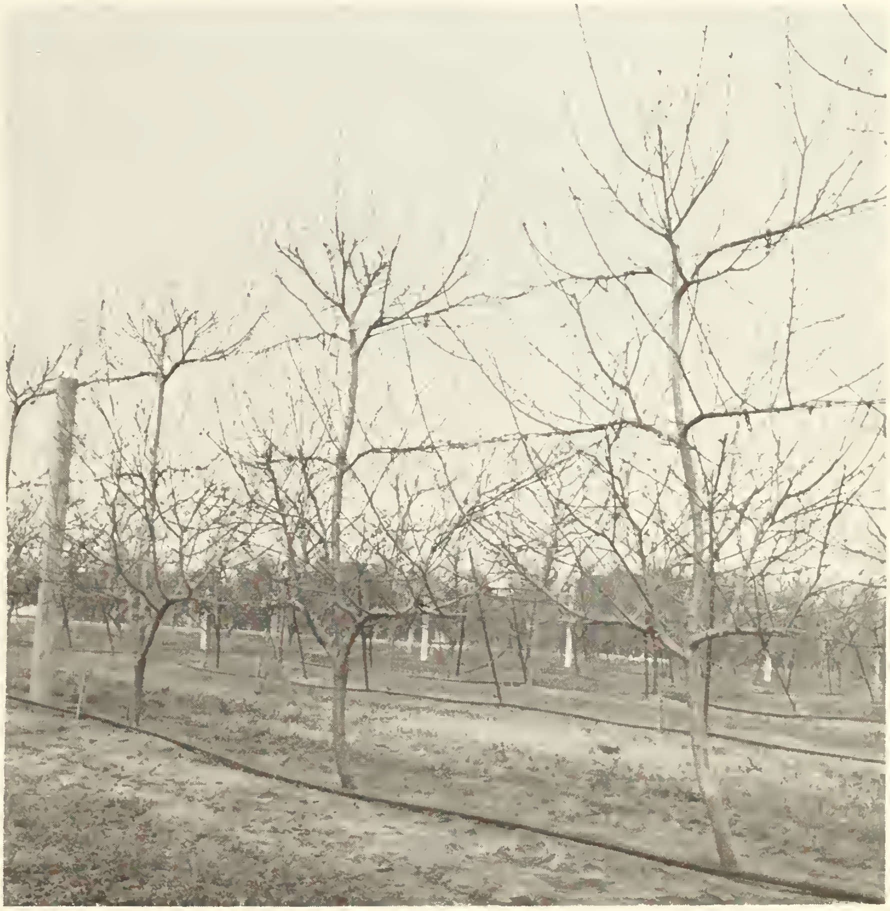


Figure 2. Trellis-trained trees showing a three-tree plot in March 1982, after two growing seasons.

August 1. The low and high rates in 1982 were 12.7 ounces and 25.4 ounces on April 9, May 21, June 26, and July 17. Applications were broadcast around each tree in a 12-inch band beginning 12 inches from the trunk. In 1981 and 1982, a 12-inch band of fertilizer was incorporated on both sides of the tree row, beginning 12 inches from the tree trunk.

An 18-inch wide weed-free band on each side of the tree row was maintained with paraquat. Natural sod developed between the rows. Standard pesticide sprays were applied as needed throughout the experiment.

Two initial nursery tree heights—2 feet (short) and 6 feet (tall)—were used for 'Harbelle' and 'Canadian Harmony' on 'Lovell' rootstock. Trees were topped to the desired height at planting. Side branches were cut off at the trunk if branches did not have the desired angle and location when trees were planted. Trunk diameters, measured 20 inches above the ground, were similar at planting for short trees (0.20 inch for 'Harbelle' and 0.20 inch for 'Canadian Harmony'), whereas trunk diameters for tall trees were 0.5-inch for 'Harbelle' and 1.1 inches for 'Canadian Harmony.'

Trees were trained as a central leader with major scaffolds spaced about 8 inches vertically around the central leader, or as a horizontal palmette trellis-trained with three wires 2 feet apart. Side shoots arising from each scaffold were headed back by hand pruning to encourage branching when they were about 8 inches long. The hedgerows were topped by hand in August when tree growth reached 7 feet high in the first season and in July and August when growth reached 8 feet in the second and third seasons. Hedgerows at maturity were pruned to 40 inches wide, 16 inches above the soil, and tapered to 30 inches wide at the top.

In 1980, central leader tree trunks were tied to 5-foot stakes to keep the leaders vertical. Stakes were removed in 1982. Tree diameters were calipered

Table 1. Design of peach hedgerow experimental orchard at MAFES Pontotoc Ridge-Flatwoods Branch Experiment Station.[1]

Tree No.	Tree Rows A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
2	B	FCC	FC	FSS	FS	FSS	FCC	FS	FC	FSS	FS	FC	FCC	FC	FS	FCC	FSS	B
3	B	S	S	T	S	T	T	S	T	T	S	S	S	T	T	T	S	B
4	B	HB	HM	HM	HM	HB	HM	HB	HM	HB	HB	HM	HB	HB	HM	HB	HM	B
5	B	FCC	FC	FSS	FS	FSS	FCC	FS	FC	FSS	FS	FC	FCC	FC	FS	FCC	FSS	B
6	B	T	S	S	T	T	T	T	S	T	S	T	T	S	S	T	S	B
7	B	HB	HB	HM	HB	HM	HB	HB	HB	HM	HM	HB	HM	HB	HB	HM	HB	B
8	B	FCC	FC	FSS	FS	FSS	FCC	FS	FC	FSS	FS	FC	FCC	FC	FS	FCC	FSS	B
9	B	T	T	S	T	S	S	S	T	S	T	T	T	S	T	S	T	B
10	B	HM	HB	HB	HM	HM	HB	HM	HB	HM	HB	HM	HB	HM	HB	HB	HM	B
11	B	FCC	FC	FSS	FS	FSS	FCC	FS	FC	FSS	FS	FC	FCC	FC	FS	FCC	FSS	B
12	B	S	T	T	S	S	S	T	S	S	T	S	S	T	S	S	T	B
13	B	HM	HM	HB	HB	HB	HM	HM	HM	HB	HM	HB	HM	HM	HM	HM	HB	B
14	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
15	B	FS	FC	FCC	FSS	FC	FSS	FS	FCC	FC	FSS	FCC	FS	FSS	FC	FS	FCC	B
16	B	S	T	S	T	T	S	T	T	S	S	T	S	T	S	S	T	B
17	B	HB	HB	HB	HB	HM	HM	HB	HM	HB	HB	HB	HM	HM	HM	HB	HM	B
18	B	FS	FC	FCC	FSS	FC	FSS	FS	FCC	FC	FSS	FCC	FS	FSS	FC	FS	FCC	B
19	B	S	T	T	S	S	T	S	S	T	S	S	T	S	T	S	T	B
20	B	HM	HM	HM	HB	HM	HM	HM	HB	HM	HM	HM	HM	HM	HB	HM	HB	B
21	B	FS	FC	FCC	FSS	FC	FSS	FS	FCC	FC	FSS	FCC	FS	FSS	FC	FS	FCC	B
22	B	T	S	T	S	S	T	S	S	T	T	T	S	T	T	T	S	B
23	B	HM	HB	HB	HM	HB	HB	HB	HM	HB	HM	HM	HB	HB	HM	HM	HM	B
24	B	FS	FC	FCC	FSS	FC	FSS	FS	FCC	FC	FSS	FCC	FS	FSS	FC	FS	FCC	B
25	B	T	S	S	T	T	S	T	T	S	T	S	T	S	S	T	S	B
26	B	HB	HM	HM	HM	HB	HB	HM	HB	HM	HB	HB	HB	HB	HB	HB	HB	B
27	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B

[1] Whole plots are defined on the plat by the rectangles with each consisting of four rows. Sub-subplots consisted of three trees per plot within a row as designated by the grouping of the tree number column. Tree number represents one tree.

[2] FC or FCC = Single or double rate of calcium nitrate. FS or FSS = Single or double rate of Sta-Green. S or T = Short or tall nursery tree. HB or HM = Harbelle or Canadian Harmony Peach. B = Border tree. Trees were spaced 6 feet in rows which were 14 feet apart.

Table 2. The influence of treatments on trunk diameter at 20 inches above soil for two cultivars at the end of each growing season for the years 1980, 1981, and 1982.

Treatments				Trunk diameter (inches)							
				Harbelle				Canadian Harmony			
Training	Tree size[1]	Fertilizer	Rate[2]	1980[3]	1980	1981	1982	1980[3]	1980	1981	1982
Trellis	Short	$Ca(NO_3)_2$	Low	0.21	0.79	1.65	2.07	0.18	0.80	1.71	2.19
			High	0.21	0.72	1.71	2.15	0.20	0.82	1.60	2.28
		Sta-Green	Low	0.20	0.71	1.65	2.01	0.23	0.71	1.51	1.98
			High	0.19	0.78	1.69	2.12	0.22	0.81	1.80	2.26
	Tall	$Ca(NO_3)_2$	Low	0.62	1.04	1.79	1.97	0.78	1.13	1.89	2.25
			High	0.67	1.12	1.77	2.23	0.76	1.14	1.84	2.28
		Sta-Green	Low	0.65	1.04	1.82	1.95	0.81	1.15	1.77	2.14
			High	0.64	1.08	1.87	2.18	0.76	1.13	1.74	2.10
Central-leader	Short	$Ca(NO_3)_2$	Low	0.21	0.73	1.61	2.12	0.19	0.75	1.66	2.34
			High	0.19	0.74	1.60	2.34	0.19	0.73	1.68	2.43
		Sta-Green	Low	0.21	0.69	1.57	2.07	0.19	0.74	1.56	2.18
			High	0.21	0.74	1.69	2.35	0.18	0.74	1.65	2.26
	Tall	$Ca(NO_3)_2$	Low	0.66	1.02	1.91	2.32	0.78	1.17	1.91	2.39
			High	0.66	1.11	1.93	2.37	0.80	1.17	2.00	2.32
		Sta-Green	Low	0.65	1.03	1.65	2.11	0.77	1.10	1.72	2.12
			High	0.73	1.15	1.93	2.31	0.81	1.17	1.93	2.32
LSD 0.05				0.08	0.13	0.22	0.21	0.08	0.12	0.21	0.23

[1] Initial tree size at planting was 2 feet (short) and 6 feet (tall).

[2] The low rate of elemental N was 0.42 ounce per tree per application in 1980, 0.84 ounce in 1981, and 1.26 ounces in 1982. The high rate of elemental N was 0.84 ounce per tree per application in 1980, 1.68 ounces in 1981, and 2.52 ounces in 1982.

[3] Initial tree diameter at planting.

20 inches above the soil at the end of each growing season.

Soil samples from the surface to 6-inch depth were analyzed yearly for nutrients beginning in 1980. Thirty-six mature leaves per sample were collected during late August from the middle of mid-level shoots of the center tree of each plot and analyzed for nutrient concentration in the Mississippi Cooperative Extension Service Soil Testing and Plant Analysis Laboratory using emission spectrographic analysis. Samples were prepared by the wet ashing method (28).

Results and Discussion

Tree Sizes

Trunk diameter differences between tree heights remained throughout the first growing season (Table 2). The appearance of trellis- and central-leader trees during the first year in the orchard is shown in Figure 3. Typical trellis- and central leader-trained trees after 2 years in the orchard are shown in Figure 4. The tall trees still had more bearing surface than the short trees. Visually, the distinction between the amount of bearing surface for central leader short and tall trees were not as great. Small trees were equal to tall trees in trunk diameter after three seasons.

Soil Analyses

The soil pH was adjusted from 5.9 to a level of 6.5 before trees were planted. The pH after 3 years was 6.6 for calcium nitrate plots and 6.0 for Sta-Green plots (Table 3). The addition of Ca from $Ca(NO_3)_2$ maintained the pH. Sta-Green did not contain Ca, thus the

Table 3. The effect of source and rate of fertilizer on soil pH, P, K, and Mg at the 0 to 6-inch depth, 2-year averages of 'Harbelle' and 'Canadian Harmony.'

		Soil content (lb/A)				Soil content (lb/A)		
		1980				1982		
Treatments	pH	P	K	Mg	pH	P	K	Mg
FERTILIZER								
$Ca(NO_3)_2$	6.1*[1]	68.1	258.4	150.9	6.6*	37.7	160.0	63.1
Sta-Green	5.6	141.5*	449.5*	149.2	6.0	111.1*	372.9*	135.7*
RATE[2]								
Low	5.9	83.4	344.7	157.6	6.3	58.9	249.2	95.1
High	5.8	126.2*	363.2	142.4	6.2	89.8	283.7	103.8

[1] Differences between fertilizers or rates within a year are significant at $\alpha = 0.05$.

[2] The low rate of elemental N was 0.42 ounce per tree per application in 1980 and 1.26 ounces in 1982. The high rate of elemental N was 0.84 ounce per tree per application in 1980 and 2.52 ounces in 1982.

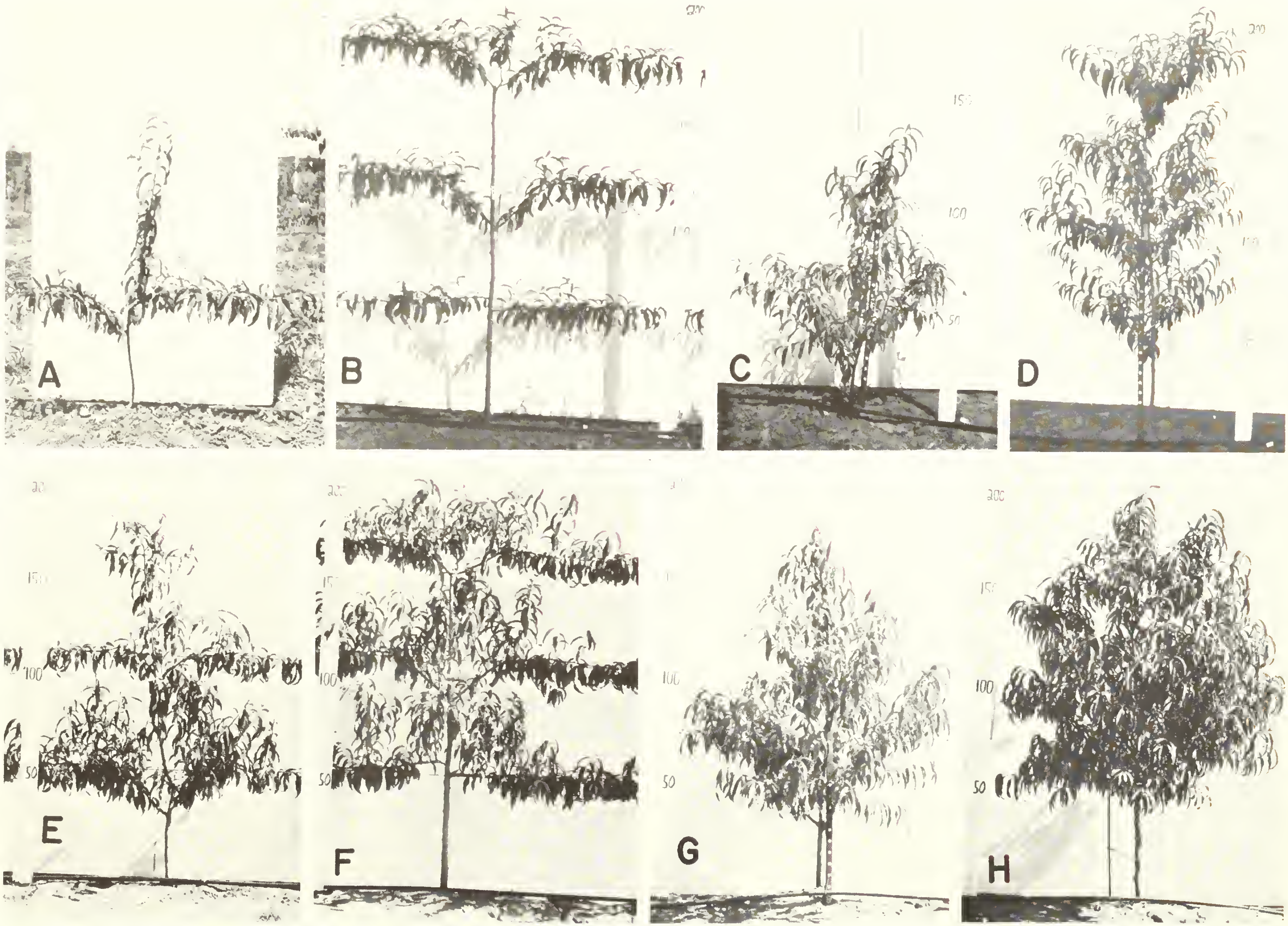
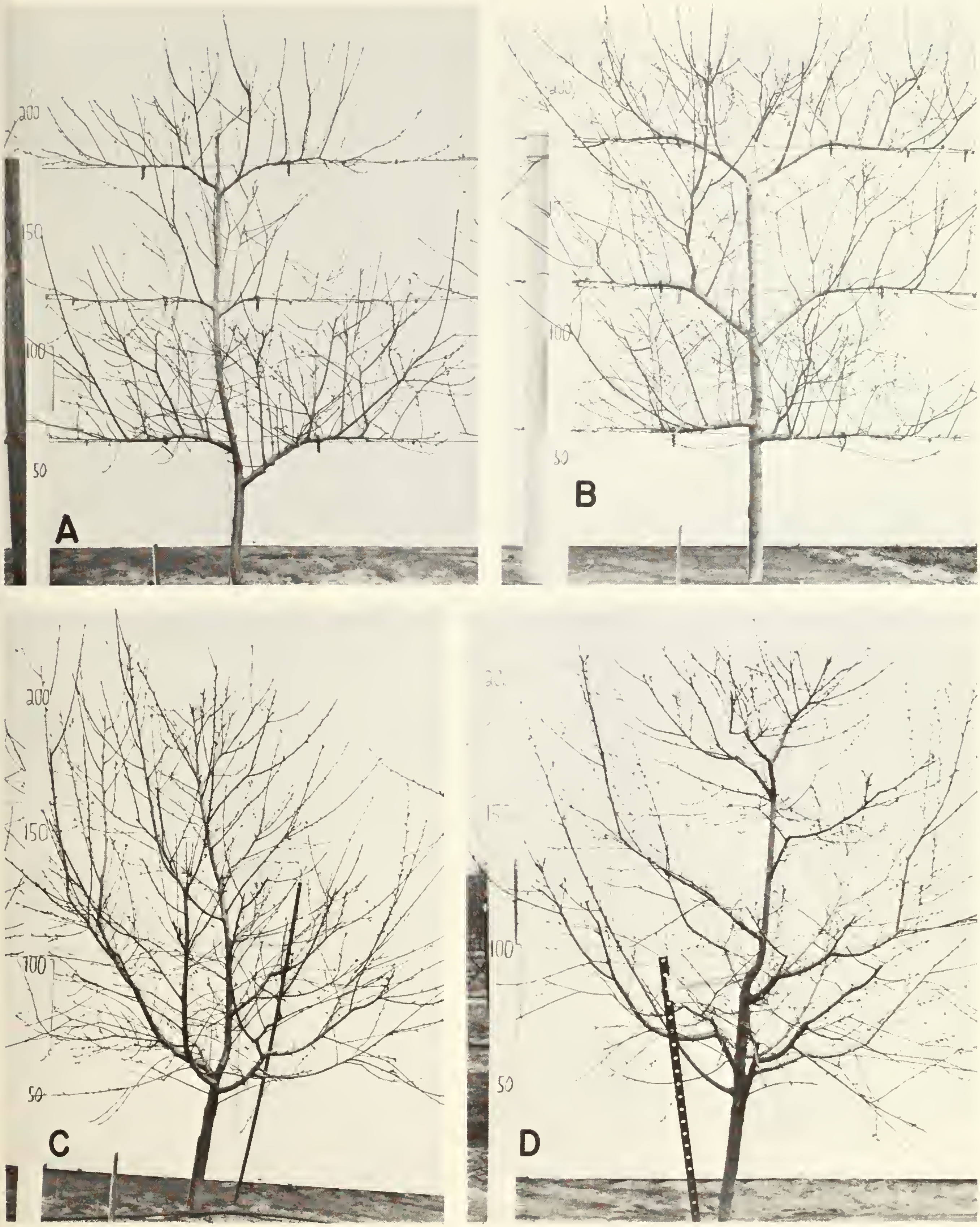


Figure 3. Typical tree systems in July 1980 (A-D) and October 1980 (E-H) of the first growing season. Trellis-trained trees: A and E short (2 feet); B and F tall (6 feet). Central leader-trained trees: C and G short (2 feet); D and H tall (6 feet). Scale is in centimeters.


200
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D

Figure 4. Dormant peach trees in March 1982, after 2 years in the orchard. Trellis-trained trees: A, short, and B, tall. Central leader-trained trees: C, short, and D, tall. Scale is in centimeters.

Table 4. The effect of source and rate of fertilizer interactions on nitrogen in leaves of two peach cultivars for 3 years.

Treatments		Leaf N (%)					
		Harbelle			Canadian Harmony		
Fertilizer	Rate[1]	1980	1981	1982	1980	1981	1982
$Ca(NO_3)_2$	Low	3.83	2.60	3.44	3.96	2.87	3.50
	High	3.83	2.97	3.66	3.94	2.95	3.40
Sta-Green	Low	3.86	2.63	3.09	3.83	2.52	3.02
	High	3.57	2.81	3.38	3.97	2.80	3.32
LSD 0.05		NS	NS	NS	NS	0.19	0.25

[1] The low rate of elemental N was 0.42 ounce per tree per application in 1980, 0.84 ounce in 1981 and 1.26 ounces in 1982. The high rate of elemental N was 0.84 ounce per tree per application in 1980, 1.68 ounces in 1981, and 2.52 ounces in 1982.

soil pH dropped. Fertilizer rates did not affect soil pH. Sta-Green increased P and K levels in 1980 and in 1982.

Leaf Analyses

Trees receiving calcium nitrate generally had a slightly higher leaf N level than trees treated with Sta-Green; however, differences were not significant (Table 4). Both fertilizers kept the leaf N within the normal range (42).

Leaf levels of P, K, and Ca (Table 5) were kept within the normal range by both fertilizers (42). Trees treated with Sta-Green showed a trend toward increased leaf K, and calcium nitrate-treated trees showed a trend toward increased leaf Ca.

Magnesium concentrations (Table 5) were within the normal range (42). Calcium nitrate-treated trees showed some increase in leaf Mg levels. Neither fertilizer contained Mg; however, after Sta-Green application, the soil pH was reduced to 6.0, which may have reduced Mg availability. The increased K levels in the soil receiving Sta-Green may have restricted Mg uptake. These factors could account for the reduced percentage Mg in the leaves of trees that received Sta-Green.

Micronutrient leaf concentrations (Table 5) were within the normal range (42). Soil applied Sta-Green increased leaf concentrations for B and Mn during the establishment year for 'Harbelle' but not for 'Canadian Harmony.' Sta-Green applications during the second and third years increased leaf B and Mn for both cultivars.

Calcium nitrate trees had increased leaf Fe concentrations in 1981. Sta-Green provided additional Fe, but Mn from the Sta-Green may have interfered with Fe absorption.

Fruit Production

'Canadian Harmony' produced more fruit on tall trees than on short trees in 1981 (Table 6). This difference did not occur in 1982. A similar trend was observed for 'Harbelle.' Initial tree sizes, as measured by trunk diameter, were smaller for tall trees of 'Harbelle' than for tall trees of 'Canadian Harmony' (Table 2). Training systems did not affect yields.

The high rate of calcium nitrate on tall 'Harbelle' trees produced more fruit in 1981 than did other treatment combinations for 'Harbelle' (Table 6). The low rate of Sta-Green in 1982 was not as effective as the high rate for fruit production. The low rate of calcium nitrate in 1982 was as effective as the high rate for fruit production (Table 6).

'Harbelle' was not thinned adequately, resulting in a low marketable fruit yield. Training systems, initial tree height, fertilizer types, or fertilizer rates did not affect marketable fruit yield.

Table 5. Effect of fertilizer on P, K, Ca, Mg, B, Fe, and Mn concentrations in leaves of two peach cultivars for 3 years.

		Concentration (% dry wt)				Concentration (ppm dry wt)		
Year	Treatments	P	K	Ca	Mg	B	Fe	Mn
HARBELLE								
1980	$Ca(NO_3)_2$	0.19	1.91	1.23	0.37	19.6	76.5	57.9
	Sta-Green	0.21*[1]	1.98	1.21	0.39	22.0*	79.9	65.3*
1981	$Ca(NO_3)_2$	0.18	2.50	2.24*	0.69	28.4	121.1*	129.1
	Sta-Green	0.18	2.64	2.13	0.63	31.3*	106.7	192.1*
1982	$Ca(NO_3)_2$	0.15	2.23	2.05*	0.57*	22.3	98.4	111.3
	Sta-Green	0.17*	2.72*	1.83	0.51	26.4*	97.7	180.4*
CANADIAN HARMONY								
1980	$Ca(NO_3)_2$	0.31	1.90	1.26	0.38	21.3	83.2	65.6
	Sta-Green	0.20	1.95	1.26	0.38	21.0	83.5	68.0
1981	$Ca(NO_3)_2$	0.17	2.30	2.18	0.70*	28.3	131.3*	144.6
	Sta-Green	0.18	2.49*	2.16	0.63	32.5*	113.4	205.1*
1982	$Ca(NO_3)_2$	0.15	2.16	2.15*	0.57*	23.4	105.8	126.4
	Sta-Green	0.16	2.57*	1.84	0.48	25.5*	106.7	188.9*

[1] Differences between fertilizers within a cultivar, element, and year are significant at $\alpha = 0.05$.

The percent of red skin and percent of soluble solids were not affected by training systems or by fertilizer types or rates (data not reported).

Summary and Conclusions

Tree training systems were not affected by the type of fertilizer or rates of N selected. Short trees were as large as tall trees after 3 years as measured by trunk diameter.

Tall trees grew adequately in the first year to produce more fruit in the second year than did short trees. Central leader, tall trees of ‘Canadian Harmony’ with the high rate of calcium nitrate had the highest yields at 12 pounds per tree or 130 bushels (48 lb/bu) per acre in 1981, the second year in the orchard. The poorest yielding combination for ‘Canadian Harmony’ in 1981 was trellis-trained short trees with the low rate of Sta-Green, producing only 1 pound per tree or 11 bushels per acre. This yield difference between tall and short trees in the second year was not observed in the third year, except in those plots receiving the low rate of Sta-Green.

The highest yield in 1982, the third year in the orchard, was achieved by ‘Canadian Harmony’ trellis-trained, tall trees with the high rate of calcium nitrate at 65 pounds per tree or 702 bushels per acre.

Calcium nitrate maintained a soil pH of 6.6 but Sta-Green lowered pH to 6.0. Sta-Green increased soil P and K levels.

Calcium nitrate increased N and Ca concentrations in the leaves. Sta-Green increased levels of P, K, B, and Mn in the leaves.

Our recommendation is to plant tall trees and use the high rate of calcium nitrate on acid soils during the first 2 years in the orchard to accent precocity.

Conventional Trees Compared

Four trees of two cultivars (‘Harbelle’ and ‘Canadian Harmony’) were trained to an open center in an adjacent row to serve as an observational check for a conventional open center orchard (Figure 5). These were planted at Pontotoc April 10, 1980. The trees were spaced 20 x 22 feet (99 trees per acre). Trees were fertilized with ammonium nitrate at the high rate per tree used in the hedgerow experiment.

The 1982 total yields from conventional open center-trained trees of ‘Harbelle’ and ‘Canadian Harmony’ were 54 and 101 pounds per tree or 5,331 and 10,015 pounds per acre, respectively. ‘Harbelle’ thus yielded 111 bushels per acre; ‘ Canadian Harmony’ 209 bushels per acre.

Open center trees of ‘Harbelle’ did not begin fruiting until 1982. ‘Canadian Harmony’ open center-trained trees had four peach fruits on one tree in 1981. Closer tree spacing of the hedgerow orchard may have increased root competition, resulting in a change to the reproductive phase earlier during the first summer the trees were in the orchard than it did for conventionally spaced trees.

The value of production based on

Table 6. The influence of treatments on total fruit yield of two peach cultivars for 2 years and on marketable yield in 1982. There were 518 trees per acre.

				Fruit yield (lb/tree)					
Treatments				Harbelle			Canadian Harmony		
Training	Tree size[1]	Fertilizer	Rate[2]	1981	1982	1982[3]	1981	1982	1982[3]
Trellis	Short	$Ca(NO_3)_2$	Low	0.99	52.78	26.57	1.30	51.96	46.21
			High	0.13	44.62	31.70	1.57	58.11	58.47
		Sta-Green	Low	0.26	43.70	32.69	0.88	43.98	41.78
			High	1.06	50.46	27.38	1.28	55.71	55.31
	Tall	$Ca(NO_3)_2$	Low	1.85	54.56	37.10	7.32	63.49	53.75
			High	5.49	64.11	28.73	7.85	64.53	56.22
		Sta-Green	Low	1.74	51.43	33.69	5.95	52.76	51.90
			High	1.37	52.54	32.17	10.12	59.24	50.31
Central-leader	Short	$Ca(NO_3)_2$	Low	0.04	44.09	28.92	1.28	58.49	49.12
			High	0.46	54.32	25.11	1.37	54.90	54.04
		Sta-Green	Low	0.07	39.64	29.76	1.46	46.58	38.49
			High	0.40	51.65	36.44	1.63	53.88	50.40
	Tall	$Ca(NO_3)_2$	Low	2.34	57.81	39.79	8.97	59.30	54.92
			High	4.83	58.91	19.22	11.88	60.08	49.36
		Sta-Green	Low	3.20	49.01	36.27	11.35	50.77	44.71
			High	2.43	59.11	32.50	6.13	59.83	52.40
LSD 0.05				2.54	9.11	12.79	2.89	8.31	11.97

[1] Initial tree size at planting was 2 feet (short) and 6 feet (tall).

[2] The low rate of elemental N was 0.84 ounce per tree per application in 1981 and 1.26 ounces in 1982. The high rate of elemental N was 1.68 ounces per tree per application in 1981 and 2.52 ounces in 1982.

[3] Marketable fruit graded 2-inch diameter and above.

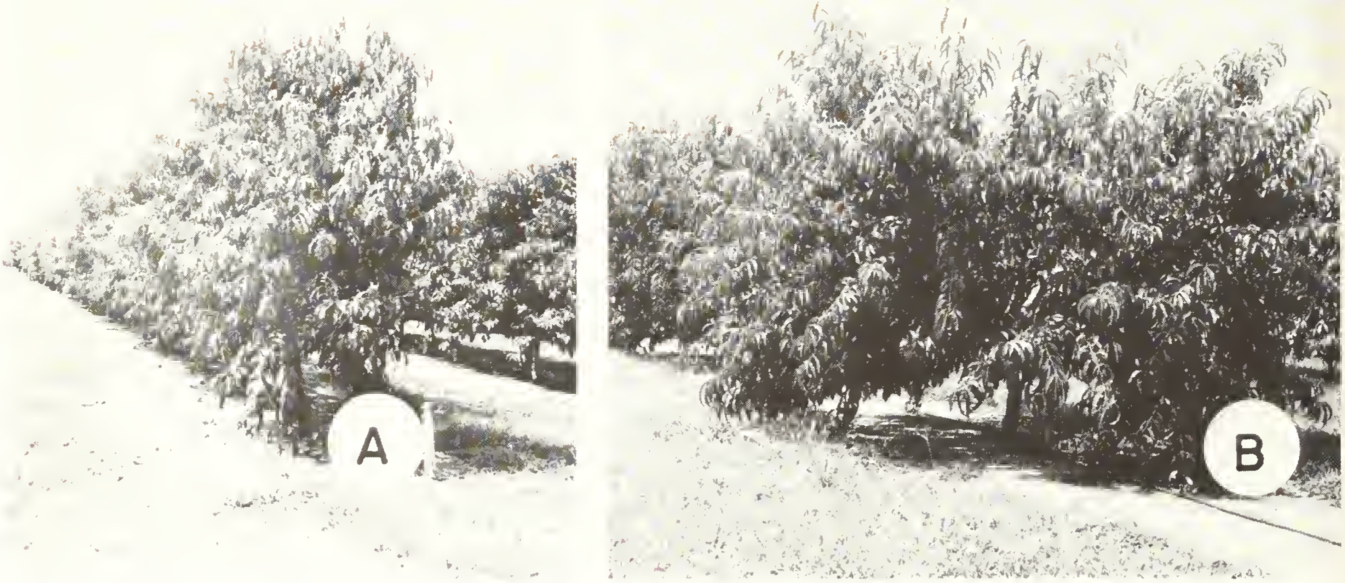

Figure 5. Hedgerow-trained trees (A-left) of 'Harbelle' and 'Canadian Harmony' spaced 6 x 14 feet, and open center-trained trees (B-right) of both cultivars spaced 20 x 22 feet, July 1982 (third growing season).

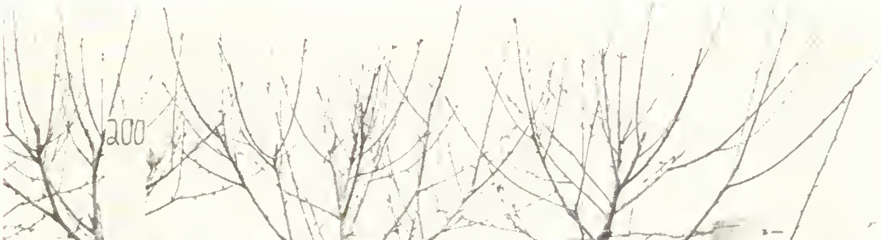

Figure 6. 'Bicentennial' fan-palmette trellis-trained tree, March 1982.

wholesale prices at South Carolina shipping points for 2-inch diameter or larger peaches per 38-pound box harvested on June 22 was $7.00 and on July 10 was $5.00 in 1981 (2); in 1982, June 21 value was $10.00 and July 9 value was $7.00 (3).

Based on these prices, the total value of production for open center-trained trees of 'Canadian Harmony' was $1,845 per acre for 10,015 pounds of peaches in 1982. The best hedgerow treatment combination in 1982 for 'Canadian Harmony' was $6,200 per acre for 33,670 pounds of peaches from trellis-trained tall trees using the high rate of calcium nitrate. Returns for the same treatment combination with 'Harbelle' was $8,730 per acre for 32,208 pounds. Price differences for 'Harbelle' reflect the higher dollar value of earlier ripening period.

Comparing the hedgerow combination with open center trees for 'Canadian Harmony,' the hedgerow system produced more than three times the dollar value of the open center method. The difference in production is due to the difference in the number of trees per acre (518 trees per acre in the hedgerow and 99 trees per acre in the conventionally spaced open center trees).

Other Systems

Fan-Palmette Hedgerow

A fan-palmette using a central leader scaffold with two scaffolds at a 45° angle to the central leader, one on either side, oriented in the tree row is shown in Figure 6. Four trees of 'Bicentennial' were trained to this method as observational border trees. Yields were comparable to those of the replicated hedgerow trees.

Candelabra-Palmette Hedgerow

Trees trained as a candelabra-palmette are shown in Figure 7. The trunk was branched at the 2 ft height. Two scaffolds were trained to the trellis wire horizontally at this height and then allowed to rebranch vertically at an interval of approximately 8 inches. Four trees of 'Bicentennial' were trained to this system as observational border trees. Yields were comparable to the replicated hedgerow trees.

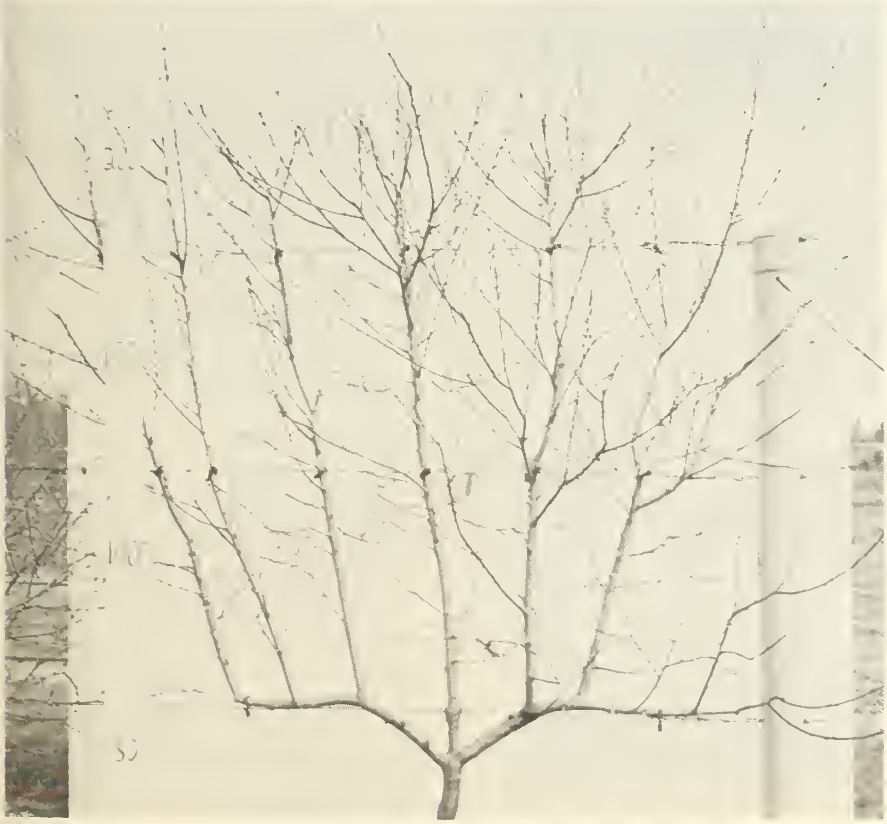

Figure 7. 'Bicentennial' candelabra-palmette trellis-trained tree, March 1982.

'Y'-Shaped Hedgerow

The senior author is shown beside a 10-year-old peach hedgerow at Byron, Georgia (Figure 8). The training system is a 'Y'-shape using 'Cornet' trees (26). This orchard had been pruned mechanically over the years and had produced crops regularly.

Hedgerow Mowing

A sickle bar mower was adapted for peach hedgerow mowing (Figure 9). The height of the mower was adjustable. The sickle bar had two cutting positions, either parallel or perpendicular to the hedgerow. The mower was used for summer and dormant mowing of the canopy. Selective hand pruning was also required.

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Bulletin 952 ◆ January 1988

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Foreword

In 1983, the Office of Technology Assessment, Congress of the United States, completed an assessment of the role of technology in the U.S. forest products industry and reported the findings of the assessment in a document entitled *Wood Use: U.S. Competitiveness and Technology.*

As a part of the overall assessment, the OTA identified opportunities for improving wood utilization, for improving forest productivity, and for enhancing the competitiveness of the forest products industry through improvements in timber harvesting technologies. To this end, the OTA recommended policy considerations to encourage research, development and transfer of forestry-related technologies, especially for timber harvesting technologies.

Congress subsequently provided special funds to establish centers at three universities to undertake the expanded research program. Mississippi State University, one of the universities selected for this role, was awarded a special research grant administered by the Cooperative State Research Service, U.S. Department of Agriculture, for this purpose.

One characteristic of the general field of forestry research is the relatively low level of funding allocated to timber harvesting research in comparison with other forestry problem areas. This is true nationally and in the southern region. As a consequence, in recent times there has been no comprehensive overview of the significant timber harvesting problems in the South. There has been no conceptual framework developed for a comprehensive southern regional timber harvesting research program, nor has there been a sufficient effort to estimate the resources necessary to support a comprehensive regional research program addressing timber harvesting problems.

An initial goal of the specially funded program at MSU was to develop a planning and priorities statement for timber harvesting research in the southern United States. By design, information to support the planning and priorities statement evolved following considerable dialogue, debate, and brainstorming among logging managers, foresters, and researchers. Three experienced and knowledgeable consultants, C. Ross Silversides, Donald M. Tufts, and Thomas A. Walbridge, were employed to prepare a report on the issues. Thereafter, a scientist from the Mississippi Agricultural and Forestry Experiment Station, Steven H. Bullard, assisted the consultants in preparing a manuscript for publication.

This publication is intended to provide research scientists, research administrators, and public policy advisors with information to assist decision making in timber harvesting research. It is hoped the publication will serve as a catalyst for increasing the awareness of timber harvesting research needs in the South.

Contents

Foreword iii

Executive Summary 1

Introduction 3

Background 3

Harvesting and Timber Availability 3

Forest Ownership and Size

Timber Harvesting and Stumpage Values

Industry Organization, Worker Training, and Mechanization 5

Organization and Worker Training

Timber Harvesting Mechanization

Objective 6

Program Description 7

Management 7

Equipment Selection

Equipment Repair and Replacement Strategies

Incentives Systems

Wood Procurement Strategies

Labor 8

Sociological Aspects

Training Programs

Methods of Payment

Selection and Retention of Workers

Ergonomics

Machines and Systems 9

Engineering Characteristics of Trees

Engineering Characteristics of Forest Stands

Engineering Characteristics of Forest Soils

Impact of Micro-Terrain on Equipment Design

Environmental Impact by Machines

Performance Capability of Harvesting Equipment

Economics 10

Tree Size, Productivity, and Cost

Terrain and Equipment Utilization

Tract Size and Volume

Harvest Intensity and Cost

Impact of Quotas

Harvesting and Stand Establishment

Changing Wood Forms and Utilization Standards

Relifing Harvesting Equipment

Economics of Truck Transport

Macroeconomic Studies

Technology Transfer 13

New Technologies 13

Electronic Data Management

Computer Software Development

Geotextiles and Plastics

Loran

Program Implementation 14

Manpower and Funding Requirements 14

References 16

Executive Summary

The U.S. South is one of the most important timber producing and processing regions in the world. The region has many forestry advantages, including extensive timber resources and proximity to major eastern and midwestern U.S. markets for wood and paper products. Timber-based industries employ about 10 percent of all southern U.S. workers, and provide about 10 percent of all income created through manufacturing in the region.

Lumber and wood products companies, furniture manufacturers, and pulp and paper producers vary in the sizes and species of timber they require as raw materials. Each segment of the industry, however, relies on the inventory of standing timber–an inventory that cannot be increased overnight. In some areas of the U.S. South, standing timber inventories are declining; more timber is being cut than is being grown. Forestry production and employment in the South can be sustained and expanded, however, if more timber is grown for future harvest and if existing stands of timber are used more efficiently.

Future timber availability in the U.S. South is closely related to the forestry perceptions of nonindustrial private landowners. The future of forestry in the region depends upon the 122 million acres owned by hundreds of thousands of individuals. Most tracts of timber that are privately owned are eventually harvested, and the economic and environmental results of the harvest have a direct impact on forestry attitudes, reinvestment plans, and future timber availability.

Technologies developed from timber harvesting research can extend *existing* timber inventories, and can also increase *future* timber availability. Research addresses the economic and environmental impediments to harvesting, and increases the proportion of timber stands that can be used commercially. This report describes the importance of timber harvesting and transportation in the U.S. South, and identifies specific research needs in six major categories:

1. **Management**–This includes research and demonstration needs of independent logging contractors. Efforts are recommended to improve skills and efficiency in selecting, repairing, and replacing timber harvesting equipment, to explore worker incentive systems for safety and production, and to examine potential wood procurement strategies. Estimated manpower and funding for the recommended 10-year program: **13 scientist-years, $1,950,000.**

2. **Labor**–This addresses research and demonstration needs of woods workers. Recommended efforts include new training program techniques and methods to select, compensate, and retain workers. Research is also recommended in ergonomics. Estimated manpower and funding for the recommended 10-year program: **15 scientist-years, $2,250,000.**

3. **Machines and Systems**–This category focuses on research needs that are primarily directed toward improved equipment application and maintenance. Research is recommended to define the engineering characteristics of trees, stands, and soils. Research in equipment design is recommended for micro-terrain adapatations and environmental effects, and specific examples of research needs in equipment performance are presented. Estimated manpower and funding for the recommended 10-year program: **21 scientist-years, $3,150,000.**

4. **Economics**–Research is needed to improve the cost and productivity of timber harvesting operations. Recommended efforts include defining new relationships between tree size, productivity and costs, terrain effects on equipment utilization times, and effects of tract size, timber volumes, and harvest intensity on costs. Studies are also recommended to define the impact of volume quotas, relationships between timber harvesting and stand establishment costs, cost impacts of new wood forms and utilization standards, equipment relifing, and the economics of truck transport. Macroeconomic studies are recommended to examine aggregate improvements in the productivity of timber harvesting. Estimated manpower and funding for the recommended 10-year program: **28 scientist-years, $4,200,000.**

5. **Technology Transfer**–Research is needed to improve the transfer of new timber harvesting methods and machines to contractors and laborers. Estimated manpower and funding for the recommended 10-year program: **3 scientist-years, $450,000.**

6. New Technologies–Examples of research needs in new technologies include electronic data management, computer software development, new materials from geotextiles and plastics, and Loran for controlling and monitoring equipment. Estimated manpower and funding for the recommended 10-year program: **13 scientist-years, $1,950,000.**

The recommended 10-year program of timber harvesting research requires an estimated **93 scientist years and $13,950,000**. The program would double the research effort in timber harvesting in the South, but would still represent less than 5 percent of total forestry research and development in the region each year. Such efforts scarcely reflect the importance of timber harvesting to southern forestry. Literally half of the value of delivered timber raw materials in the South is attributed to harvesting and transportation. Most of the millions of acres of timberland in the South will be harvested at some time–and the men, methods, and machines used in the harvest will directly impact the economic and environmental success of commercial forestry, today and in the future.

Problems exist in many areas of timber harvesting, from systems that are relatively labor intensive (above) to systems that are highly mechanized and capital intensive (below). Problems are addressed in the areas of: *Management, Labor, Machines and Systems, Economics, Technology Transfer,* and *New Technologies.*

Planning and Priorities for Timber Harvesting Research in the Southern United States

Introduction

In 1982, the United States Senate Committee on Appropriations requested the Office of Technology Assessment (OTA) to undertake on its behalf an inquiry into the technologies related to the growth and use of U.S. timber resources. The results of this inquiry were published in August 1983 as *Wood Use: U.S. Competitiveness and Technology.* OTA identified timber harvesting and associated problems as prime targets for research to improve production cost efficiencies, long term productivity and the Nation's wood supply.

Timber harvesting in the southern U.S. is a $3 billion per year industry. Harvesting research has a direct impact on the industry, and on the timber-growing profits of thousands of private nonindustrial landowners each year, yet most forestry research funds are allocated to other subjects. The OTA (1983), for example, reported that 70 percent of the USDA Forest Service research and development budget is allocated to growing, protecting, and inventorying trees, while less than 3 percent is devoted to improving timber harvesting.

The present report describes problems and constraints to improved timber harvesting and transportation in the southern U.S., and presents priorities for research. The "Background" section of the report describes the importance of timber harvesting and associated problems in the region. The section also summarizes timber harvesting research, and explains why agencies such as OTA have concluded that such research is vital to U.S. interests. The next sections are "Objective" and "Program Description". These sections include topics and priorities for a recommended 10-year timber harvesting research program in the southern U.S. Final sections describe "Program Implementation" and estimated "Manpower and Funding Requirements".

Background

Timber harvesting is an integral part of commercial forest management, yet most textbooks on forest management have little or no discussion of harvesting technologies. Textbooks on timber harvesting, however, clearly describe a close relationship between harvesting and forest management, a relationship that has existed for many years:

> *"Logging constitutes a very large part of the practice of forestry in our North American forests. It may be good, poor, or indifferent forestry, but logging is the important part of forestry in which our woods are treated and a future supply of timber is assured, or the areas are left in an unproductive condition. Harvesting the woods requires more capital and labor than any other phase of forest work and is, therefore, the principal business of the woods."* (Nelson C. Brown, 1934, *Logging*).

> *"The harvesting of timber crops according to correct forestry methods is the key to most other forestry operations. Timber harvesting may logically be considered the principal operation in forestry in that the culmination of all forestry effort is a merchantable tree for service to mankind. Harvesting, therefore, is one of the most important operations in forestry, entirely aside from the fact that it provides the income necessary to carry on the whole forestry business."* (Wackerman, Hagenstein, and Michell, 1966, *Harvesting Timber Crops*).

The relationship between harvesting and forest management is especially important in the U.S. South, where landowner perceptions of the economic and environmental results of commercial forestry are extremely important. As background to establishing research priorities, two important features of timber harvesting and forestry in the southern U.S. are discussed: "Harvesting and Timber Availability" and "Industry Organization, Mechanization, and Training."

Harvesting and Timber Availability

Domestic and world markets for U.S. forest products are expanding, yet annual timber removals are exceeding growth for commercially important species in some regions of the country. Only very recently has the potential timber shortfall in the U.S. South been realized.

The USDA Forest Service released a review draft of *The South's Fourth Forest: Alternatives For the Future* in March 1987. The basic objectives of the southern timber study were to determine the type of forest presently developing in the South, and to determine what type of forest would be of greatest benefit to U.S. society. Although the review draft will be revised before publication, major conclusions are not likely to be changed. The "Highlights" section of the draft contains the following statements:

> *"Timber removals have been rising steadily because of increased harvests and for softwoods are above net annual growth over large areas in the South.*
>
> *"The base projections in this study show timber removals rising above net annual growth and declines in inventories–in the 1990's for softwoods and beyond 2000 for hardwoods.*
>
> *"The base projections of resource change mean that the South is facing a future of rising stumpage and roundwood prices, much lower rates of growth in timber harvests, and declines in employment in the forest industries."*

The Forest Service study also shows tremendous opportunities to increase timber production in the South, and to sustain high levels of timber-related employment. The study provides new evidence of the need to harvest and process *existing* stands efficiently, as well as the importance of encouraging timber production for *future* harvest. Timber harvesting research addresses both of these issues.

Increased efficiency in harvesting timber is a direct result of many research efforts. Studies of machine design and application effectively extend existing timber supplies. Greater efficiency means less timber left on the site, and may also allow harvest of areas otherwise economically or physically beyond the logger's reach. Timber harvesting research can also affect future production, however, by encouraging private nonindustrial landowners to reinvest in forestry. Research may result in direct incentives such as higher stumpage values, and may also result in less site and stand damage from logging. The potential influence of harvesting research on future timber availability in the South is demonstrated by forest ownership and size patterns, and the total value of stumpage harvested in the region each year.

Forest Ownership and Size. There are nearly 182 million acres of timberland in the South (U.S. Forest Service 1987), and ownership and size characteristics present challenges to logging practitioners and researchers. In contrast to Canada and the U.S. Pacific Northwest, timberland in the U.S. South is primarily in private ownership. Public agencies administer 10 percent, companies in the forest industries own and lease about 23 percent, leaving more than two-thirds of the region's timberland in nonindustrial private ownership.

There are nearly 2 million nonindustrial private forest (NIPF) landowners in the South, and typical tract sizes are small. Harvesting operations, therefore, encounter smaller average tract sizes and smaller average tree sizes than in many areas of the world. The Office of Technology Assessment (1983) emphasized the need to develop harvesting equipment for use on small forest tracts, targeted to diverse objectives of small landowners.

Timber Harvesting and Stumpage Values. Standing timber provides wildlife habitat, forest recreation, and watershed protection, as well as raw material for producing solid-wood and paper products. Timber may, therefore, have value for different reasons, depending on its location, characteristics, and ownership. The value of stumpage for producing lumber and other wood products is the result of asking "How much can a buyer afford to pay for timber and still cover all costs and make a satisfactory profit?" (Duerr 1985). The answer depends on the value of the wood products processed from the timber, and on the costs of harvesting, transporting, and manufacturing the timber from forest to final product (Figure 1). Lower logging and hauling costs therefore result in higher stumpage values–buyers can afford to pay more for standing timber. When this results in greater returns to timber growers, reinvestment in active forest management is encouraged.

The economic magnitude of timber harvesting and transportation in the U.S. South is illustrated in Figure 2. In 1984 alone, standing timber valued at $3.1 billion was harvested, and the roundwood was valued at more than $6 billion at local points of

Wood Products' Selling Prices
− Manufacturing Costs
− Hauling Costs
− Logging Costs

Stumpage Value– **the value of standing timber is the value of wood products, minus the costs of harvesting, hauling, and processing the timber.**

Figure 1

delivery. Harvesting and transporting timber to rail sidings, concentration yards, and other delivery points added more than $3 billion to the value of standing timber sold in 1984 (U.S. Forest Service 1987).

Industry Organization, Worker Training, and Mechanization

Organization and Worker Training. The structure and organization of the logging industry in the southern U.S. is an important factor in setting priorities for current and prospective timber harvesting research and development. Some forest products companies in the region maintain their own logging crews, but independent contract loggers with an average of fewer than six employees comprise the largest portion of the South's logging industry. A dominant characteristic of the industry is the very large number of very small firms.

Another important characteristic of contract logging firms in the South is that owners and workers often have not been trained adequately in efficient, safe, and environmentally sound harvesting methods. In Sweden, half of the recent increases in productivity are attributed to machine operator training programs. Worker training would certainly improve the pulpwood logging industry's safety record and reduce Worker's Compensation Insurance rates, which in the state of Mississippi, for example, are a staggering **$76 per $100 of payroll** for unmechanized operations.

Although there are natural differences in employment conditions, worker training, and capital requirements between woods operations and processing facilities, the degree of difference is especially great in the southern U.S. A clear image of the disparity between southern mill and woods operations was presented by Berger (1972):

> *"When I first arrived in the South and looked at a modern paper mill, it suddenly occurred to me that paper men were either the greatest optimists this world has ever known or the biggest gamblers. Here, men were gambling that the voracious appetites of hundreds of millions of dollars worth of highly automated plants were going to be fed by a "rag tag" assortment of vehicles that looked like refugees from a junk yard. But somehow the armada groped its way out of the woods, dragged itself down the roads and highways and fed the ravenous chippers.*
>
> *"When we walk inside a paper mill we find a highly*

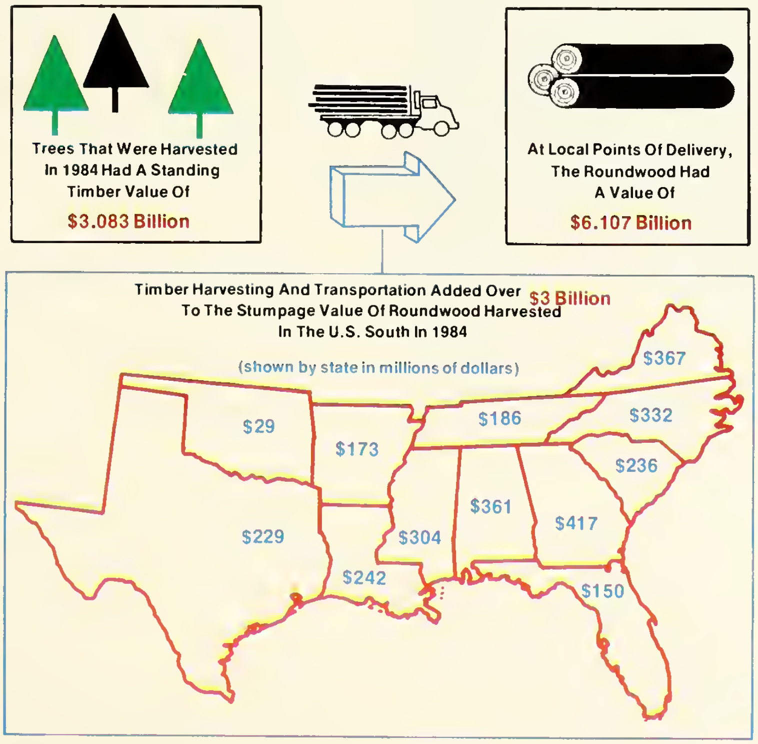

Trees That Were Harvested
In 1984 Had A Standing
Timber Value Of
$3.083 Billion
At Local Points Of Delivery,
The Roundwood Had
A Value Of
$6.107 Billion
Timber Harvesting And Transportation Added Over $3 Billion
To The Stumpage Value Of Roundwood Harvested
In The U.S. South In 1984
(shown by state in millions of dollars)
$367
$332
$186
$29
$173
$236
$361
$417
$229
$304
$242
$150

Figure 2

controlled process in operation. A competent staff of well-trained employees exercise the control and technology necessary to produce the paper products of the twentieth century. The quality of the employee is readily apparent in a brief discussion with any one of them.

"The picture changes dramatically when we go into the woods from which the raw materials are emerging. Here we find some men signing their paychecks with "X's," working in the mud, mosquitoes, snakes, briars—men sweating in the summer and shivering in the winter; men who haven't expected much or received much from life."

Improvements have been made since the image above was described, but there are still many organizational and training problems that need to be addressed in the industry. Training programs for loggers have encountered difficulties, for example, from the reluctance of companies to deal directly with woods labor. For reasons of legal liability, an arm's length relationship between firms producing roundwood and firms consuming roundwood is maintained. This relationship ensures that woods workers are not deemed to be employees of firms purchasing roundwood. It is very difficult to initiate and support training programs for woods workers, except through the cooperation of the contractors themselves.

Timber Harvesting Mechanization. Since World War II, machine use in timber harvesting has increased dramatically in most areas of the world. Timber felling, for example, has progressed from axes and crosscut saws, to bow saws, to chain saws, and to machines with shears or circular-saw felling heads. General advances in technology are only partly responsible for increased mechanization in timber harvesting:

"The mechanization of timber harvesting is a long-term dynamic process, the ultimate aim of which is to ensure an adequate supply of wood at a cost acceptable to processing plants. The form of the wood produced, whether lumber or wood fibre, will be determined by the end-usage. An intensification of mechanization in timber harvesting today is the result of a number of factors: the rise in the level of technology generally, the need for cost maintenance or cost reduction on behalf of the forest-based industries, the need for increased man-day productivity because of the shortage of adequately trained labor, and the availability of capital for investment in heavy and relatively costly equipment.

With the intensification in the mechanization of timber harvesting, mental attitudes and ways of thinking about these operations have to be or are being changed. Timber harvesting is changing from a plant cropping operation to an operation producing industrial raw material. The industrial production approach is being extended beyond the mill walls into the forest" (Silversides 1972).

The American Pulpwood Association in a recent policy paper (1985) stated:

"Partial mechanization is certainly achievable but there are still some barriers to full mechanization. Interest in concept development for full mechanization (prototypes) has fallen dramatically. The industry may be in a period in which the further spread of partial mechanization will be the predominant technical achievement. If the past is a key to the present, major effort towards full mechanization with emphasis on handling small diameters will again occur, probably spurred by labor shortages and resulting shortages of pulpwood. In addition, applied studies on ergonomics (the fit between man's work habits and machines) could well result in the major future productivity increases."

In the absence of a comprehensive research and development program on the mechanization of harvesting, U.S. research has focused largely upon designing and developing individual machines. Comprehensive programs in Canada, Western Europe, and Scandinavia have worked toward integrated harvesting systems designed to fit specific timber resources, harvesting requirements, and manufacturing processes. The U.S. Forest Service has carried out some regional studies on the mechanization of harvesting systems, but these have been constrained by budget and priorities. Private sector efforts in the U.S. have primarily been by trial and error, in small job shops, and by adapting agricultural and construction equipment.

Objective

There are many problems that constrain the biological effectiveness and economic efficiency of timber harvesting in the southern U.S. These problems arise from such factors as fragmented forest land ownership and diverse goals, diverse forest stand and terrain conditions, differing market conditions for various types of industrial wood, and the size, organization, and capabilities of logging operations.

The objective of the present study has been to identify the major problem areas that physically and economically constrain timber harvesting in the South. A 10-year research planning statement has been developed to serve as a guide for future timber harvesting research. The planning statement includes a list of priorities for the identified problems, and estimates of the manpower and funding needed to carry out the proposed program.

Program Description

As a result of meetings with individuals and a brainstorming session with a widely representative group of industry operators, academics and researchers, six problem areas in timber harvesting were identified: **management, labor, machines and systems, economics, technology transfer, and new technology.**

1. Management

The future prosperity of the logging industry in the South depends in large part on the decision-making skills of individual contract loggers. Loggers are vital to the present and future southern forest products industry, and efforts should be made to increase their business knowledge, their capacity to manage people, and their receptiveness to new ideas involving methods and equipment.

Within this problem area, four major contractor responsibilities have been selected as priority topics for research. These are equipment selection, equipment repair and replacement, labor incentives, and timber procurement. Specific research projects should be developed and the results transferred to logging contractors.

Equipment Selection. Loggers must know for each site what timber is to be cut, what roads must be constructed, and what environmental limitations are placed upon their work. The limitations, production capacity, operating range, and cost of different machines must be known. Contractors must achieve balanced machine combinations to benefit from optimum logging systems. More than 70 percent of loggers responding to a recent survey indicated that their most important equipment-related problem is how to achieve a mix of equipment that allows an even flow of production (Reed 1985).

Equipment Repair and Replacement Strategies. The profitability of a logging firm depends in large part on managerial decisions respecting equipment repair and replacement. A number of methods of analysis have been developed to help logging contractors decide when to repair and when to replace equipment. For each machine there is an optimum time to sell or trade, a time determined by factors such as depreciation, maintenance downtime and cost, and technical obsolescence.

Incentive Systems. Innovative wage incentive systems can lower unit production costs, improve production output, and raise employee's earnings. There are many forms of incentive programs–some are based on individual performance, some on group or crew performance, and some include mechanics, with production depending upon machine availability. To be successful, incentives must provide a direct link between work performance and compensation.

The system selected should be simple so that employees can understand it and compute their own pay. It should also provide for changes in method, and should not restrict potential earnings. The possible impact of new wage systems has been demonstrated for timber harvesting systems in Sweden (Werner 1986). Since nationwide changes in how Swedish forest workers are paid began in 1975, productivity and the frequency and severity of woods accidents have changed significantly.

Wood Procurement Strategies. Four wood procurement strategies are commonly used by forest products companies in the U.S. South: owning land for timber harvest, leasing land for timber harvest, assisting private nonindustrial forest landowners to increase timber production on their lands, and buying wood on the open market (Kronrad et al. 1985). These strategies should be evaluated from the position of timber buyers as well as timber sellers. Wood procurement policies influence corporate profits and stability of raw material sources, as well as timber-growing profits and perceptions of NIPF landowners.

"The future prosperity of the logging industry in the South depends in large part on the decision-making skills of individual contract loggers."

2. Labor

In the past 20 years, the tasks performed by forest workers have changed. Different skills are required today than was the case even 10 years ago. Periodic surveys have established the number, age, education, and experience of loggers and other woods workers. Continuing surveys are needed to clearly characterize the work force and to provide a better knowledge base for training programs to improve their efficiency and safety.

Training Programs. Training programs for forest workers should be carefully evaluated to ensure they reflect current needs. New techniques and equipment for training forest workers should also be evaluated. Equipment simulators, audio-visual and other classroom aids, for example, should be considered for on-the-job teaching and demonstration. In an industry which is becoming more and more technical, experience isn't necessarily the best teacher.

The organization of the forest industry precludes some companies from developing direct relationships with woods labor. Woods labor typically is employed by a logging operator under contract to the conversion plant. Under these circumstances, training programs should be conducted by state or university extension services working with the logging contractors. Contractors and other interested parties must coordinate efforts to improve labor/management relations.

Employee Compensation. Wage incentive systems were presented earlier as an important issue for management. These systems are also important to labor. Pay incentives should be readily understood by workers, and should specifically encourage production and safety goals. Innovative systems need to be developed and tested.

Selection and Retention of Workers. Studies and trials of various methods of employee selection should be undertaken. Logging contractors with stable, highly productive labor forces should be analyzed to determine how they have succeeded where others have failed. Stable labor forces have better safety and production records than those with high turnover. As woods work changes from individual labor to crew or team work, labor turnover becomes move disruptive and results in greater hidden costs.

Scientific management is responsible for many of today's confrontations with labor. In timber harvesting and the extraction of other primary products, men have often been considered as easily replaceable extensions of machines. Such attitudes are changing, however, and employee participation in production decisions is increasingly encouraged.

Ergonomics. Basic studies in ergonomics (man-machine relationships) are almost non-existent in the southern logging industry. Such studies are extremely important to improved timber harvesting. The human part of the man-machine system has a direct impact on safety, performance, and productivity. Proposed studies of forest machinery should include the operator's perceptions on ease of operation, safety, and comfort, as well as ease of service and maintenance.

"The human part of the man-machine system has a direct impact on safety, performance, and productivity."

"... research is needed to understand and mitigate potential adverse efferts on soils, water, and remaining or succeeding vegetation."

3. *Machines and Systems*

Rather than recommending research on new equipment concepts and development, the 10-year research program recommended for machines and systems emphasizes operating and maintaining existing equipment.

Engineering Characteristics of Trees. In addition to tree diameter and height, information on width of crown, weight of components, branch size and arrangement, and center of gravity is essential for improved harvesting equipment design and application. Mechanized harvesting of small timber concerns many forest products companies, logging contractors, and public and private landowners. Accumulating felling heads are currently popular for small timber. They permit felling and handling trees in multiples, and have clear advantages in productivity and cost over single-tree felling methods. Continuous felling machines designed to accumulate trees in larger bunches may be the next development in harvesting small timber. Prototypes of such machines exist in the A-line Swather (Prince Albert Pulp Ltd., Prince Albert, Saskatchewan, Canada) and the Canadian National Research Council short rotation harvester.

Engineering Characteristics of Forest Stands. Stand characteristics have a direct impact on timber harvesting operations. Tree spacing, for example, influences the movement of machines within a stand. Understanding the effects of stem spacing could result in greater machine mobility and higher productivity.

Visibility is also an important characteristic of forest stands. Visibility varies among stands of different species, densities, and ages, and at different times of the year. Underbrush in forest stands directly impacts timber harvesting, particularly thinnings, whether workers are on the ground or operating machines.

Engineering Characteristics of Forest Soils. Trafficability is the capability of a machine to pass over terrain, with or without a load. Mobility involves the time a vehicle requires to pass over terrain and complete its mission. Trafficability and mobility are important concepts in timber harvesting, whether dealing with skidding tractors, forwarders, harvesters, or trucks. Both concepts depend upon soil strength, a characteristic which often depends upon soil moisture. A major problem affecting timber harvesting is wet weather and its impact upon soil strength and machine trafficability. The application of Thornthwaite's evapotranspiration work should be explored. The work applies to soil moisture, and thus indirectly to soil strength. It may permit the prediction of soil conditions and scheduling of harvesting operations for various soils following rains of different intensities.

In the past, most soil trafficability studies have involved agricultural and military machines and machine applications. Most forestry studies have investigated soil compaction by wheels and tracks, and the effects of such compaction on stand establishment and tree growth. Research is needed to increase our knowledge of these relationships.

Micro-Terrain and Equipment Design. Micro-terrain determines the ground clearance needed and the speed at which vehicles can travel in the woods. Micro-terrain thus affects operator comfort and machine control at different speeds. Terrain profile data and analyses are needed to provide equipment designers and manufacturers with information for producing machines which can automatically adjust their speed to ground conditions, and machines which can adjust to the vibrations encountered by the operator.

Environmental Impact by Machines. Timber harvesting can dramatically alter a forest environment, and research is needed to understand and mitigate potential adverse effects on soils, water, and remaining or succeeding vegetation. Timber harvesting can adversely affect sites, for example, by compacting the ground and creating ruts, possibly causing erosion and reducing future timber growth rates. Soil and water impacts must be considered in designing and applying timber harvesting systems for clearcuts and partial cuts, for different forest environments encountered in the South.

Thinnings are specialized timber harvests, often designed to promote the volume and value growth of residual trees. The environmental consequences of thinning include damage to roots and stems of residual trees, as well as to soils and water. Soil compaction and rutting, and root and stem damage can be controlled through improved equipment design and operation. Machines designed specifically for thinnings in the U.S. South, for example, must be relatively small and maneuverable. New or modified types of running gear, and spring- or shock-absorber suspension systems are needed to help reduce soil compaction, ruts, and root system wounds. Sideways and tractive slip causes tear wounds on root systems and tree boles. These problems may be addressed through research on steering geometry and torque control through hydrostatic transmissions.

Performance Capability of Harvesting Equipment. Machine performance depends on how well a machine is designed, and how well it is applied to the type, extent, and conditions of work required (Figure 3). Machine size is important to performance, yet size must be considered in relation to machine form and other design factors. A general study of the morphology of forestry machines is needed as background to specific studies of machine design and application. Some specific studies needed are:

Relationships between tire widths and soil impacts on different sites,

Cost and benefit relationships between wide, low-pressure tires and dual tires,

Comparisons of choker, grapple, and clam bunk skidders under different timber and site conditions,

Comparison of tandem bogie versus single large wheel (could affect the design and configuration of many forestry machines), and

Potential application of all-terrain vehicles in thinnings and on small tracts (including their use with skidding arches, load-carrying trailers, and other equipment).

In addition to the examples above, machine designs and applications that have been successful in the U. S. South and elsewhere in the world should be evaluated for potential use in the southern U.S. As examples, adding unpowered axles may increase vehicle load capacities; "Big Stick" loaders may serve a dual purpose if used to skid or winch felled trees; and an inexpensive yarder similar to the "Logger's Dream" should be re-evaluated for the increasing number of tree-length and full-tree harvesting operations.

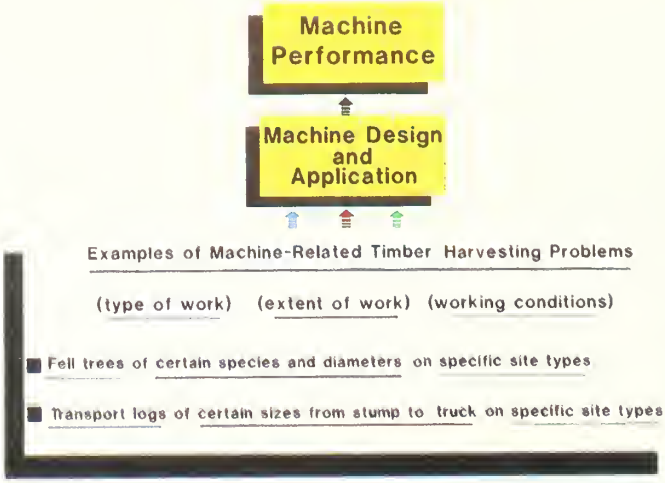
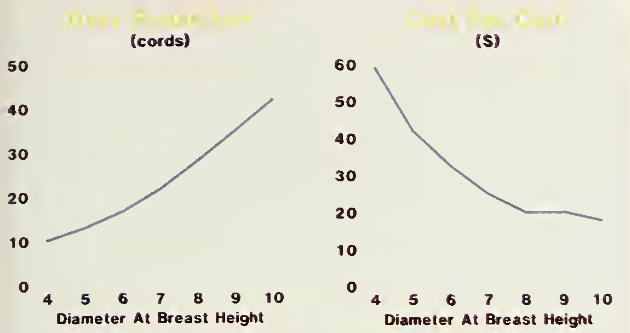
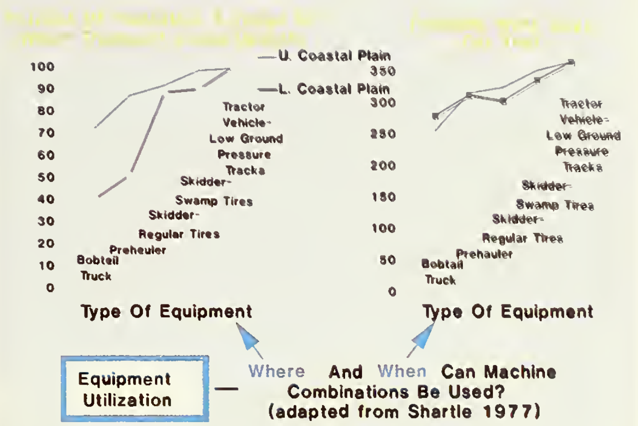

Machine Performance
Machine Design and Application
Examples of Machine-Related Timber Harvesting Problems
(type of work)
(extent of work)
(working conditions)
Fell trees of certain species and diameters on specific site types
Transport logs of certain sizes from stump to truck on specific site types.

Figure 3



Production And Costs By Diameter Class --
Includes Cutting, Skidding, Loading And Overhead For Tree-Length Logging, Chainsaw Felling And Cable Skidding (Tufts 1977)

Figure 4



Where And When Can Machine Combinations Be Used?
(adapted from Shartle 1977)

Figure 5

4. Economics

The economics problem area includes a number of issues which affect the cost and productivity of harvesting operations. Some of these issues have been studied previously, but all are worthy of more intensive study and effort to improve industry awareness of the findings.

Tree Size, Productivity, and Cost. Most semi-mechanized logging systems in the South have lower production rates and higher per-unit harvesting costs when harvesting smaller trees (Figure 4). As new harvesting equipment is developed and applied, research is needed to describe new production/cost/tree size relationships. The influence of tree size on productivity and cost is especially important in southern forests. Since 1952, there has been a 22-fold increase in the inventory of southern pine plantations (U.S. Forest Service 1987). Average tree sizes are smaller for plantations than for natural pine stands. The Forest Service projects that within 15 years, more than 35 percent of southern softwoods will be in plantations.

Terrain and Equipment Utilization. Equipment utilization has two aspects—*where* and *when* can the equipment be used? Figure 5 presents an example for various in-woods transport equipment for pine plantations in two regions of the Atlantic Coastal Plain. The percent of plantations which are operable shows *where* the equipment can be applied, and possible work days per year indicates *when* the machines can be used. Figure 5 represents a relatively small region of the South, and similar studies are needed for different machines, terrain, and stand types in the region.

Tract Size and Volume. Tract size and volume directly affect harvesting costs and production rates:

"Literature and research support the conclusion that large tracts (50 to 125 acres) have significant economic advantages over small tracts (less than 50 acres). Average costs increase rapidly on tracts below 50 acres and are prohibitive on tracts below 10 to 20 acres" (Cubbage 1983).

"Low volume per se, not low volume per acre, is the cause for inefficient and expensive forest harvesting and management" (Garratt 1957).

Studies are needed to define the potential for reducing harvesting costs by consolidating forest tracts in the South through purchase, cooperative agreement, or other means.

Harvest Intensity and Cost. Harvest intensity depends on stand conditions and forest management objectives. Harvesting productivity and costs may differ greatly for clearcuts and partial cuts, and therefore may affect the unit price a landowner receives for standing timber. The relative costs and benefits of different harvest intensities need to be established for different stand and market conditions.

Impact of Quotas. Forest products companies benefit from the high productivity, freedom from strikes, and relatively low capitalization of contract loggers. These loggers usually have substantial financial commitments for logging equipment, however, and depend on the cash flow from weekly or monthly production. When a wood-consuming mill imposes a quota on wood, loggers may have cash-flow problems; many such cases result in bankruptcy. Quotas affect the stability of the logging industry, and benefits, costs and alternatives should be investigated thoroughly.

Harvesting and Stand Establishment. The equipment needed to prepare a site for planting or seeding after harvest depends on the logging debris, stumps, and trees left on the site. Relationships between slash characteristics and machine size and effectiveness in site preparation have not been fully developed. If low cutting feller-bunchers are used, for example, and entire trees are removed from the site, what is the effect upon subsequent site preparation operations? In some areas of the South, unmerchantable trees are harvested for energy, further reducing debris after logging, and site preparation costs for planting or seeding. In addition to the direct costs of harvesting and regenerating a timber stand, environmental effects must be considered. More intensive harvesting may allow greater use of site preparation methods that do not require heavy machinery and soil disturbance (Bullard and Watson 1986). Further study is needed to define cost and environmental trade-offs between timber harvest and site preparation intensities for different site and stand conditions in the U.S. South. Studies of timber harvesting and site preparation should consider new site preparation and stand establishment methods. Intermittent-furrow or injection planting machines, for example, are better suited to rough, cutover land than the continuous-furrow machines presently used in the South. Today's site preparation practices may in turn impact future timber harvesting. When stands originate from bedded sites, for example, ditches and mounds may become obstacles to harvesting equipment (Shartle 1977).

Changing Wood Forms and Utilization Standards. Wood-processing firms constantly strive to reduce raw material and processing costs. Examples of these changes include pulping of sawmill residues, chip storage outside mills rather than roundwood storage at mills, the use of whole tree chips, changes in species mix, and the increased use of 5D wood (dead, down, dying, diseased, and defective). Processing changes include the use of smaller trees by sawmills, and the use of different raw materials for particle board, waferboard, and other panel products that are replacing plywood in many applications. Continuing study of the changing forms and specifications of wood raw materials is needed as fiber and solid-wood requirements evolve over time.

Relifing Harvesting Equipment. Relifing is an equipment strategy often used in the aircraft industry. Old machines are completely rebuilt to the mechanical efficiency of new machines. Relifing is a cost-effective strategy under some equipment cost-price structures. Studies are needed to identify potential cost savings from relifing harvesting and site preparation equipment.

Economics of Truck Transport. Opportunities to reduce the transportation costs of wood moved by truck must be identified. The need to recognize cost differences in hauling timber is clearly shown by a study conducted for the Canadian Department of Transportation: *Operating Costs of Trucks in Canada–1984*. On a ton-mile basis, it costs over twice as much to haul bulk commodities across Canada with a two-axle, gas-powered truck than with a five-axle, diesel truck with semi-trailer. Although transporting timber in the southern U.S. involves labor costs, fuel costs, and load limits different from those of Canada, the cost saving possibilities in the South merit study. The 1979 American Pulpwood Association producer census, for example, showed that 50 percent of pulpwood trucks used in the South were two-axle, gas-powered units, and more than 60 percent of them were over 6 years old.

Economic engineering studies are needed to evaluate conventional three- axle trucks, two-axle semi-trailer combinations, and other transportation options in the U.S. South as tree-length timber harvesting and transportation become more important. In some cases, actual trucking tests may not be necessary. The Cummins Engine Company, Inc., of Columbus, Indiana, for example, has developed a vehicle mission simulation program to help choose the vehicle with the optimum power train combination for the work involved. Information on optional gear ratios for logging trucks considering reasonable combinations of highway mileage, secondary road mileage, and expected slope conditions for different areas of the South needs to be develcped using operations research techniques.

Specific studies of all phases of truck logging operations are needed to provide information on potential reductions in production costs. Loading, for example, may be accomplished with self-loading trucks or with independent loaders. Standing time for trucks in the woods should be minimized. The best time may depend on timber volume to be loaded, truck capacity, and length of haul. After loading, on-the-road driving skills are important factors influencing costs. Gear shifting practices should be evaluated through tachometer tests. Delays in unloading trucks reduce hauling efficiency and production. Charges for demurrage at the mill or the use of shuttle trailers should be studied. The traffic flow at wood-receiving facilities should be analyzed using operations research techniques.

Macroeconomic studies. Very few macroeconomic studies of the logging industry or its major sectors have been undertaken. Such studies are needed to understand aggregate improvements in the productivity of capital and labor in the South. Microeconomic and cost studies are common, but do not indicate the performance of timber harvesting at the industry level.

5. Technology Transfer

New technology in timber harvesting is distributed in published material, workshops and demonstrations, and through the increased use of video technology and educational television programs. More effective transfer of new knowledge related to timber harvesting, is needed throughout the southern United States. Failure to apply new technologies wastes valuable resources, and leads to social and economic penalties. Logging contractors and woods laborers must receive new technologies to develop safe, cost efficient, and competitive operations.

Although adoption is lagging, new knowledge is accumulating at an increasing rate. The gap between what is known and what is applied continues to widen. Direct, purposeful transfer of technology is essential for increased adoption. It has been proposed that efforts concentrated in a few "centers of excellence" offer a greater chance of long term success than spreading the effort widely. Such "centers of excellence" must include practical training, however, or they may become prestigious centers of learning out of touch with the people actually doing the job in the field (Richards and Axelson 1986).

6. New Technologies

Electronic Data Management. Equipment to record, analyze, and print inventory, cost, and production data is available, but is not widely used in the logging industry. Its introduction into the timber harvesting industry should be accelerated.

Computer Software Development. Universities should cooperate with private industry in software research, development and application in timber harvesting. Microcomputer software has already been used in some feller bunchers and harvesting machines, but has not been widely adopted. Microcomputers can greatly improve consistency and efficiency of work in repetitive tasks, and additional research and development is needed to expand their use in timber harvesting.

Geotextiles and Plastics. Many new materials are available for application in harvesting operations. The use of geotextiles in forest roads and landings, and millyards should be investigated. Such materials may extend the harvesting period and reduce lost equipment time. New fibers, such as Kevlar, are used in off-road tires and safety clothing, and new plastics are available to replace metal in machines to decrease weight and improve performance, and to replace steel cables and chains in skidding and loading operations.

Loran. Loran (long-range navigation) has a number of potential uses in forestry, in fire fighting, and in spraying operations. It can be used to monitor the location and movement of a fleet of vehicles or other equipment from a control center. Research is needed to investigate the extent to which this technology can be used to improve the efficiency of timber harvesting.

"The gap between what is known and what is applied continues to widen. Direct, purposeful transfer of technology is essential for increased adoption."

Program Implementation

The nature and complexity of the problems identified, the research opportunities suggested, and the potential payoff from successful research and demonstration in timber harvesting require a major commitment from public agencies, universities, and companies with forestry interests. It is unrealistic to think that these problems will be solved in the near term. Therefore, a commitment to a sustained timber harvesting research effort is recommended to achieve the potential contribution of such a research program to long-term economic growth and productivity, the well-being of the southern forests and forest environment, and to the present and future generations of forest workers and landowners.

Manpower and Funding Requirements

Total research and development expenditures in forestry exceed $49,000,000 per year. About $1,000,000, or approximately 2 percent, are spent on forest engineering research each year. The 1984 sawtimber harvest in the South was valued at over $6 billion at the first delivery point, with stumpage comprising about half of this value. Only 2 percent of the total forestry research budget is addressing problems associated with 50 percent of the production in value of delivered wood; that is, only $1,000,000 are being spent annually on investigating problems of an industry which produces more than $3 billion in value each year.

The expenditure of funds proposed in this report is significant and represents a much larger commitment of resources to timber harvesting and related research than is currently allocated. Recommended research expenditures are small, however, in comparison with research expenditures on other forestry activities in the South. Further, recommended research expenditures are small in comparison with the production values involved.

Research subjects are prioritized under the six general headings of the proposed program (Table 1). Data required to accurately estimate the costs of the recommended research are lacking. However, it was assumed that a scientist-year costs $150,000, an adjustment from the 1977 figure used by the U.S. Forest Service (Callaham 1981). The scientist-year cost includes operating costs, and capital and personnel costs to support a scientist, and may therefore include the cost of one to four technicians or mechanics.

No attempt has been made to specify which research topics might be undertaken by governmental agencies, universities, or the private sector. Not all projects would begin or end at the same time because of constraints on funding, facilities, and manpower. Over the proposed 10-year period, however, the recommended program could be implemented at an average annual cost of $1,395,000. While this expenditure would more than double the present annual expenditure on timber harvesting research in the South, it would still amount to only 4.7 percent of total forestry research and development expenditures in the region.

Table 1. Recommended 10-year program of research in timber harvesting and transportation.

Priority Number	Subject	Estimated Scientist-years	Funding At $150,000 Per Scientist-year
	Management		
1	Equipment Selection	4	$ 600,000
2	Equipment Repair and Replacement Strategies	4	600,000
3	Incentive Programs	2	300,000
4	Wood Procurement Strategies	3	450,000
		13	$ 1,950,000
	Labor		
1	Sociological Aspects	3	450,000
2	Training Programs	2	300,000
3	Methods of Payment	2	300,000
4	Selection and Retention of Workers	3	450,000
5	Ergonomics	5	750,000
		15	$ 2,250,000
	Machines and Systems		
1	Engineering Characteristics of Trees	3	450,000
2	Engineering Characteristics of Forest Stands	3	450,000
3	Engineering Characteristics of Soils	4	600,000
4	Impact of Micro-terrain on Equipment Design	3	450,000
5	Environmental Impact by Machines	4	600,000
6	Performance Capability of Harvesting Equipment	4	600,000
		21	$ 3,150,000
	Economics		
1	Tree Size, Productivity, and Cost	2	300,000
2	Terrain and Equipment Utilization	3	450,000
3	Tract Size and Volume	2	300,000
4	Harvest Intensity and Cost	3	450,000
5	Impact of Quotas	2	300,000
6	Harvesting and Stand Establishment	4	600,000
7	Changing Wood Forms and Utilization Standards	3	450,000
8	Relifing Harvesting Equipment	2	300,000
9	Economics of Truck Transport	4	600,000
10	Macroeconomic Studies	3	450,000
		28	$ 4,200,000
	Technology Transfer		
1	Studies on Various Techniques of Technology Transfer	3	$ 450,000
	New Technologies		
1	Electronic Data Management	5	750,000
2	Computer Software Development	5	750,000
3	Geotextiles and Plastics	2	300,000
4	Loran	1	150,000
		13	$ 1,950,000
5	(Note: Due to rapid rates of technological change, additions may be required.)		

Recommended Program 10-Year Totals.

Program Description	Estimated Scientist-years	$
Management	13	$ 1,950,000
Labor	15	2,250,000
Machines and Systems	21	3,150,000
Economics	28	4,200,000
Technology Transfer	3	450,000
New Technology	13	1,950,000
TOTAL	93	$13,950,000

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Table of Contents

Page

List of Tables v

List of Figures v

List of Appendix Tables v

Introduction 1

Model Plant Facilities and Equipment 2

Real Estate 2
Building Requirements 2
Waste Treatment 3
Parking and Loading 4
Processing and Equipment 4

Estimated Investment Requirements and Annual Costs for Two Scenarios of a Model Plant 7

Investment Requirements 7
Annual Ownership Costs 7
Annual Operating Costs for Scenario I 8
Annual Operating Costs for Scenario II 10
Annual Cost Analysis 11

Hauling Costs 12

Annual Ownership Costs 13
Annual Operating Costs 14
Hauling Cost Analysis 14

Summary, Conclusions, and Limitations 15

List of References 16

Appendix 17

List of Tables

Table Page

1 Estimated land requirements for a synthesized shrimp processing plant, Mississippi Gulf Coast, 1986 4

2 Estimated investment requirements and percentage of initial cost, by specific item, for a synthesized processing plant, two operating scenarios, Mississippi Gulf Coast, 1986 ... 7

3 Estimated annual ownership costs, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986. 8

4 Estimated total labor costs, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986 8

5 Estimated annual operating costs, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986. 9

6 Estimated annual costs, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986 10

7 Estimated annual cost components expressed in cents per pound for a synthesized shrimp processing plant, two operating scenarios, Mississippi Gulf Coast, 1986 ... 11

8 Estimated annual cost components expressed as a percentage of total costs for a synthesized shrimp processing plant, two operating scenarios, Mississippi Gulf Coast, 1986 11

9 Estimated initial investment per truck for live-hauling and ice-packed hauling of freshwater shrimp, 1986 12

10 Estimated total annual costs and costs per pound of two methods of hauling freshwater shrimp 50 miles one-way from farms to two synthesized processing plants, 1986 13

List of Figures

Figure Page

1 A schematic of real-estate requirements for the model plants 2

2 A schematic of the model plant with product flow 3

3 An illustration of the wash/receiving tank 5

4 An illustration of the flume breaking table 5

5 Schematic of one 1,000-pounds-per-hour grader and receiving tank.............. 6

List of Appendix Tables

Table Page

1 Monthly landings of gulf marine shrimp, annual and five-year averages, Northern Gulf region, 1981-1985 18

2 Data used for estimating annual ownership cost for processing and hauling freshwater shrimp, Mississippi Gulf Coast, 1986..... 18

3 Estimated annual depreciation, interest on average investment and repair and maintenance costs for all durable assets, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986 19

4 Estimated number of pieces and cost of office equipment, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986 19

5 Estimated number of employees by wage and salary scale, by job classification, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986 20

6 Estimated salary and fringe benefit costs, by job classification, two scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986 20

7 Estimated number of motors and horsepower, efficiency, and number of operating hours per motor, by item of equipment, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986 21

8 Estimated annual electricity costs, by equipment item, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986 21

9 Manufacturer suggested daily water requirements for a synthesized shrimp processing plant operating at capacity, by item, Mississippi Gulf Coast, 1986 22

10 Results of time-motion studies concerning hand processing of freshwater shrimp, recorded in pounds per minute, and performed by a seven-man crew, Mississippi State University, 1986.......................... 22

Cost of Processing and Hauling Freshwater Shrimp in Mississippi

Introduction

The interest of researchers and farmers in Mississippi and throughout the Southern Region of the United States concerning the economic feasibility of producing and marketing freshwater shrimp continues to grow. From 1984 to 1985, landings of marine shrimp in the United States increased by 31.9 million pounds to a total of 333 million pounds [13]. It is believed that these landings may have reached a peak [10, 11], due in part to loss of vital estuaries and declining water quality.

The United States imports more than 50 percent of its marine shrimp supply [13]. With the consumption of shrimp growing in other developed nations in conjunction with a leveling off of world wide landings of marine shrimp, any increases in the supply of shrimp in the Unites States will come only through cultured species–either imported or produced domestically.

Recent experiments by Mississippi Agricultural and Forestry Experiment Station (MAFES) scientists concerning production of fresh-water shrimp (*Macrobrachium rosenbergii*) in small ponds have been encouraging. These experiments are being continued with the objective of developing techniques that will result in profitable production systems. However, regardless of production regime, adequately assessing the market potential for freshwater shrimp requires knowledge about the total cost for freshwater shrimp at the retail level. Since assembling and processing costs may comprise a significant portion of that total cost, a reliable estimate of assembly and processing costs must be obtained before the economic feasibility of producing and marketing freshwater shrimp can be assessed.

Objectives

The general objective of this study was to estimate costs for assembling and processing freshwater shrimp. More specific objectives were to:

1. Synthesize an efficient processing plant capable of assembling, processing, and storing an assumed quantity of freshwater shrimp;
2. Define plant processing procedure in terms of distinct phases of operation and identify all equipment and labor needs for each phase;
3. Estimate total investment, annual ownership, and annual operating costs for the synthesized plant under selected capacities; and
4. Identify feasible methods of transporting shrimp an assumed distance from farms to the processing plant, and estimate transport costs.

Methods and Procedures

Objective 1 was begun by assuming a quantity of shrimp to be processed by the plant. The assumed quantity was based on a daily processing capacity that is within the range of existing Gulf Coast plants. The synthesized plant would have a capability of processing in a 2-month period the quantity of freshwater shrimp that would be produced from 1,000 acres of ponds, assuming an average yield of 1,500 pounds (live weight) per acre.

The technology assumed is the most efficient technology currently available for processing shrimp into the green headless frozen form. Possible alternative technologies were not investigated. The synthesized plant was then divided into phases of operation.

In Objective 2, equipment requirements of each phase and equipment prices (with a few exceptions) were provided by appropriate suppliers. Other prices were obtained from published sources [4]. Building costs were obtained from personal interviews with building manufacturers and contractors. Land costs were obtained from a Mississippi Cooperative Extension Service specialist located on the Mississippi Gulf Coast. Labor requirements were obtained from interviews with processors, manufacturers' specifications, and some limited time-motion studies performed by MAFES researchers during the processing of the 1985 experimental crop.

Only one size of plant was synthesized; however, two levels of operating capacity were assumed. First, it was assumed that the plant would process marine shrimp for 7 months and freshwater shrimp for 2 months, resulting in a 9-month operation (Scenario I). Operating hours per month assumed for each of the 7 months of processing marine shrimp were based on

5-year average monthly landings of northern gulf marine shrimp (Appendix Table 1). Second, it was assumed that the plant would process only freshwater shrimp, and consequently, would operate only for 2 months of the year (Scenario II). The data obtained for satisfying Objectives 1 and 2 were also used to derive annual ownership and operating costs for both plant scenarios in Objective 3.

In Objective 4, costs for hauling shrimp from production ponds to the processing plant were estimated for two methods of hauling: iced in refrigerated trucks, and live-hauling. Costs of live-hauling shrimp were derived from an earlier study of live-hauling catfish [7]. Costs of hauling in refrigerated trucks were based on data obtained from shrimp processors, and on truck costs associated with live-hauling. The quantity of live shrimp per load in live-haul trucks was based on a preliminary density test conducted during the harvest of the 1985 MAFES crop.

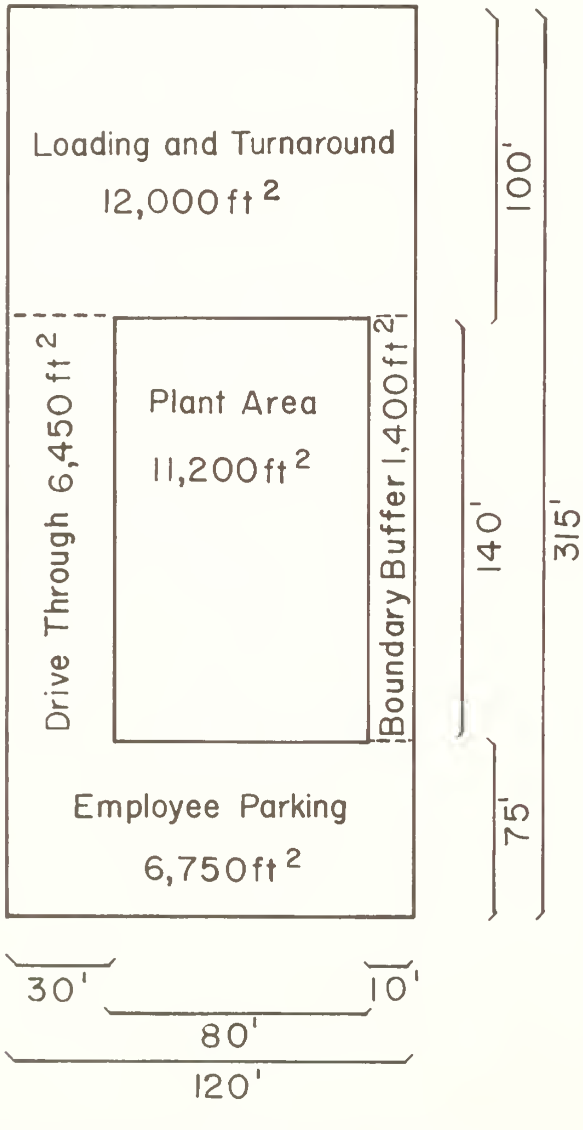

Figure 1. Schematic of real estate requirements for the model plants.

Model Plant Facilities and Equipment

All land, building, and equipment requirements necessary for processing green headless shrimp are presented in this section, by phases of operation. The synthesized model plant has the capacity to process 2,505,600 pounds of headless shrimp in 9 months (Scenario I) or 691,200 pounds of headless shrimp in 2 months (Scenario II). During the peak of processing, plant capacity was based on 10 hours per day, 6 days per week. Scenario I assumes processing at capacity during June-October only. No processing would be done during January-March. For other months, processing at the following percentages of capacity is assumed: May and November, 75; December, 50; and April, 25. Under Scenario II it was assumed that the plant operates at capacity during the 2 months September and October, and would process no shrimp during the other 10 months.

Real Estate

The most important locational factors for a processing plant under Scenario I are proximity to the Gulf and accessibility by truck and shrimp boat. Therefore, waterfront property, on a bay or inlet with a pier, is required. The processing plant requires a waterfront of 120 feet, with total required space of 37,800 square feet, as illustrated in Figure 1. Land costs for this area with waterfront averaged $1,000 per front foot for lots of this general size [15].

A plant processing only freshwater shrimp (Scenario II) would not require waterfront property. Average cost of land in the same general area, but not waterfront property, was estimated to be $30,000 an acre [15].

Land requirements for both scenarios included space for the turn-around and unloading area, employee parking, drive-through, and 10-foot spacing between plant and property line. The plant site needs to be accessible by a public paved road and be served by electricity, water, and sewage. To meet the requirements for reduced insurance rates, the plant should be located within city limits, or in an area served by a fire department, and be accessed by a paved road.

Building Requirements

Several factors were important in determining the cost of a modern shrimp processing plant, with the type of building and topography of the land being significant factors. The synthesized plant in this study was assumed to be constructed on level ground built up an additional 5 feet higher than its original base of 10 feet above sea level [15].

The construction of the building consisted of an inner masonry wall surrounding the processing floor with an exterior of metal siding reinforced by steel beams placed every 20 feet. The concrete slab floor required a depth of 6 inches due to the weight of equipment.

The plant's floor plan was based upon what was considered necessary to adequately house the required equipment as defined by equipment dimensions, space for working labor, and walkways. The "required equipment" was determined from the desired daily and annual processing capacity of the plant. Average construction costs for the building, including the slab, masonry, plumbing, electrical, etc., were estimated to be $28 per square foot [12]. A schematic showing the processing area layout of equipment and dimensions is presented in Figure 2.

Waste Treatment

The method of effluent disposal utilized was based upon the most common method employed by marine shrimp processors along the Mississippi Gulf Coast [15]. It was assumed that liquid or dissolved effluents that meet state requirements would be piped back into the bay.

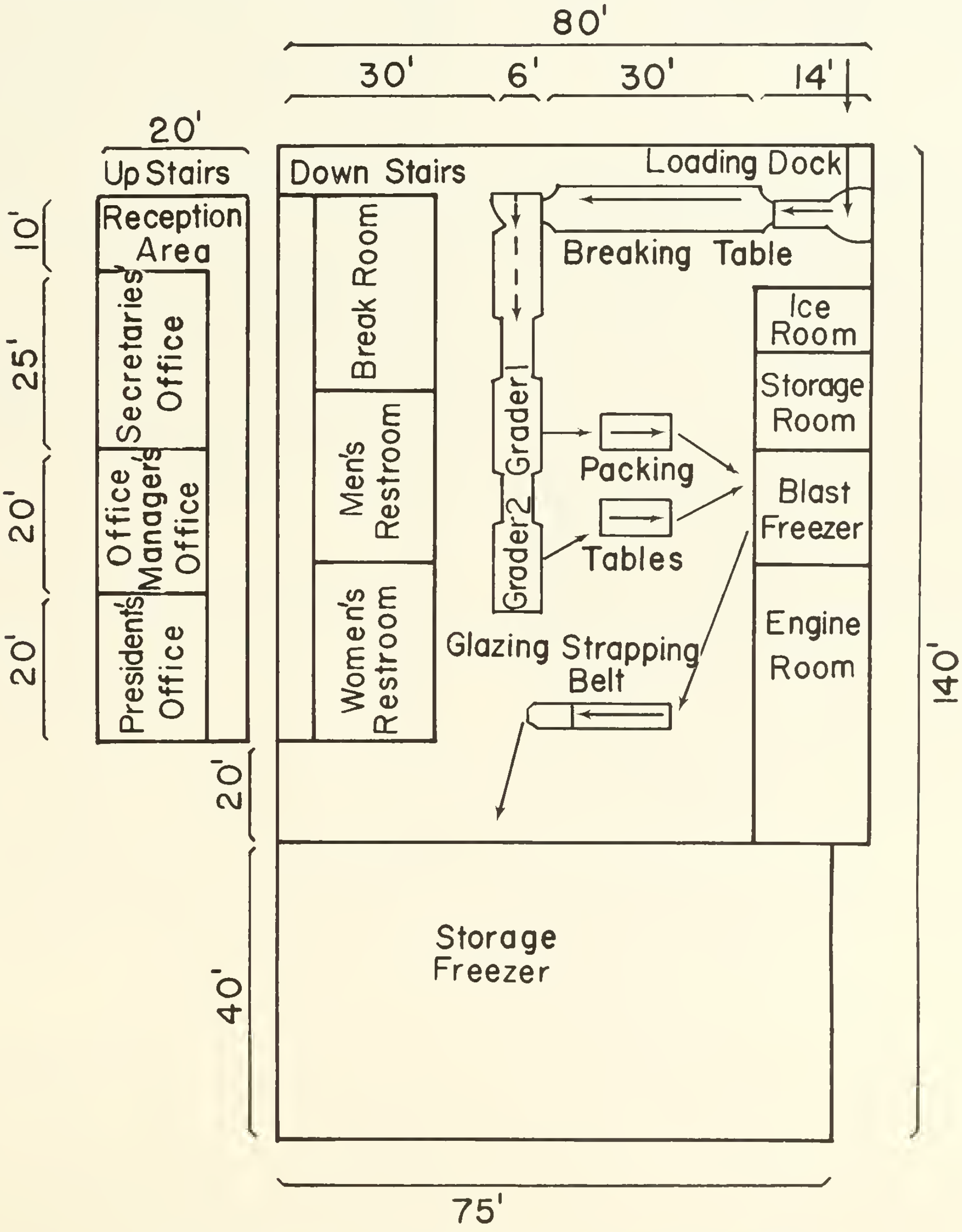
80'
30'
6'
30'
14'
20'
Up Stairs
Down Stairs
Loading Dock
Reception Area
Secretaries' Office
Managers Office
Office
President's Office
Break Room
Men's Restroom
Women's Restroom
Breaking Table
Grader 1
Grader 2
Packing
Tables
Ice Room
Storage Room
Blast Freezer
Engine Room
Glazing Strapping Belt
Storage Freezer
10'
25'
20'
20'
20'
40'
140'
75'

Figure 2. Schematic of the model plant with product flow.

Solid effluent wastes, consisting mostly of broken heads and discarded shells, would be collected in perforated baskets and screened drains. The collected solid effluent (approximately 16,000 pounds per day) would be placed in daily collectable dumpsters. The daily collection rate, at the time of this study, was $28 per loaded dumpster, while the rent for the dumpsters was $75 per month [3].

Parking and Loading

Requirements for parking and loading space were estimated to be .43 acre. This estimate was based on 270 square feet required parking space for every two employees and 12,000 square feet for the loading and unloading of trucks [4]. Space requirements for parking and loading are displayed in Table 1.

Table 1. Estimated land requirements for a synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

Facility Area	Amount
	(sq. ft.)
Building	11,200
Turnaround and unloading[a]	12,000
Parking	6,750
30-foot drive-through	6,450
Miscellaneous[b]	1,400
Total land	37,800

[a] Includes parking for trucks.

[b] Consists of area around building for buffer.

Processing Equipment

Equipment costs include all equipment necessary to process green headless shrimp. Each piece of equipment is categorized by phase in the processing cycle. The various phases of the cycle are: (1) receiving; (2) breaking; (3) grading; (4) packing; (5) blast freezing; (6) glazing; and (7) storage freezing. All equipment comprising the plant's processing technology is included in Appendix Table 2.

Receiving

There are few equipment requirements for the receiving phase. Since the shrimp are delivered to the plant in wooden crates aboard refrigerated trucks, a forklift is necessary for crate transfer from the trucks onto the loading dock. (The shrimping industry typically trades unprocessed shrimp by the "barrel," which contains 210 pounds of shrimp and 100 pounds of ice. The contents of two wooden crates make a "barrel" when each crate contains 105 pounds of shrimp and 50 pounds of ice.) The forklift, which is also used inside the plant, was assumed to be electric. After the crates are unloaded from the truck, the shrimp are removed by hand from the crates into an automated wash receiving/tank.

This particular receiving tank consists of an automatic float system, adjustable overhead freshwater spray system, ice baffle, volume control paddle, and a conveyor belted overflow drain for the regulated delivery of the product to the breaking table [8]. An illustration of the receiving tank is shown in Figure 3.

Breaking

Breaking, or the removal of the shrimp heads, is performed by hand as "breakers" pick the shrimp off of an open stainless steel transporting belt and separate the head from the tail. The remaining tail portions of the shrimp are placed into a free-flowing flume trough. The flume, which is located on both sides of the transport belt, discharges the tails into another ice baffled receiving tank. The breakers, who are positioned on a platform on both sides of the flume breaking table, place the removed heads into stainless steel funnels. These discarded heads are removed, weighed, and discharged into dumpsters.

It was assumed that 32 experienced head breakers together could break an average of 1,500 pounds of tails per hour. This assumption is based on interviews of plant managers and verified by time-motion studies conducted by MAFES scientists (see Appendix Table 10). All exposed metal portions of the flume system are of stainless steel. A diagram of the flume breaking system is provided in Figure 4.

Grading

The shrimp tails are placed into the flowing flume and deposited into another automated ice baffle, rinsed, and transported to the grading machine conveyor belts. These elevated conveyor belts carry the shrimp tails to the mechanical graders where they are dropped into the water-lubricated, fully adjustable grading rollers [8]. The graders sort shrimp according to a preset size category and deposit the shrimp tails down side shoots into perforated plastic baskets. Thus, each basket contains only shrimp tails within a narrowly defined size range. A diagram of one of the two graders required in the model plant's grading system is presented in Figure 5.

Packing

The packing phase of the synthesized processing plant is also accomplished by hand labor. The sized shrimp tails are carried in perforated baskets from the grader to one of three stainless steel packing tables. Each table is 4 feet by 8 feet in dimension with two electronic scales at one end. The shrimp are weighed according to size count, and placed 5 pounds per properly labeled box. These polyethylene

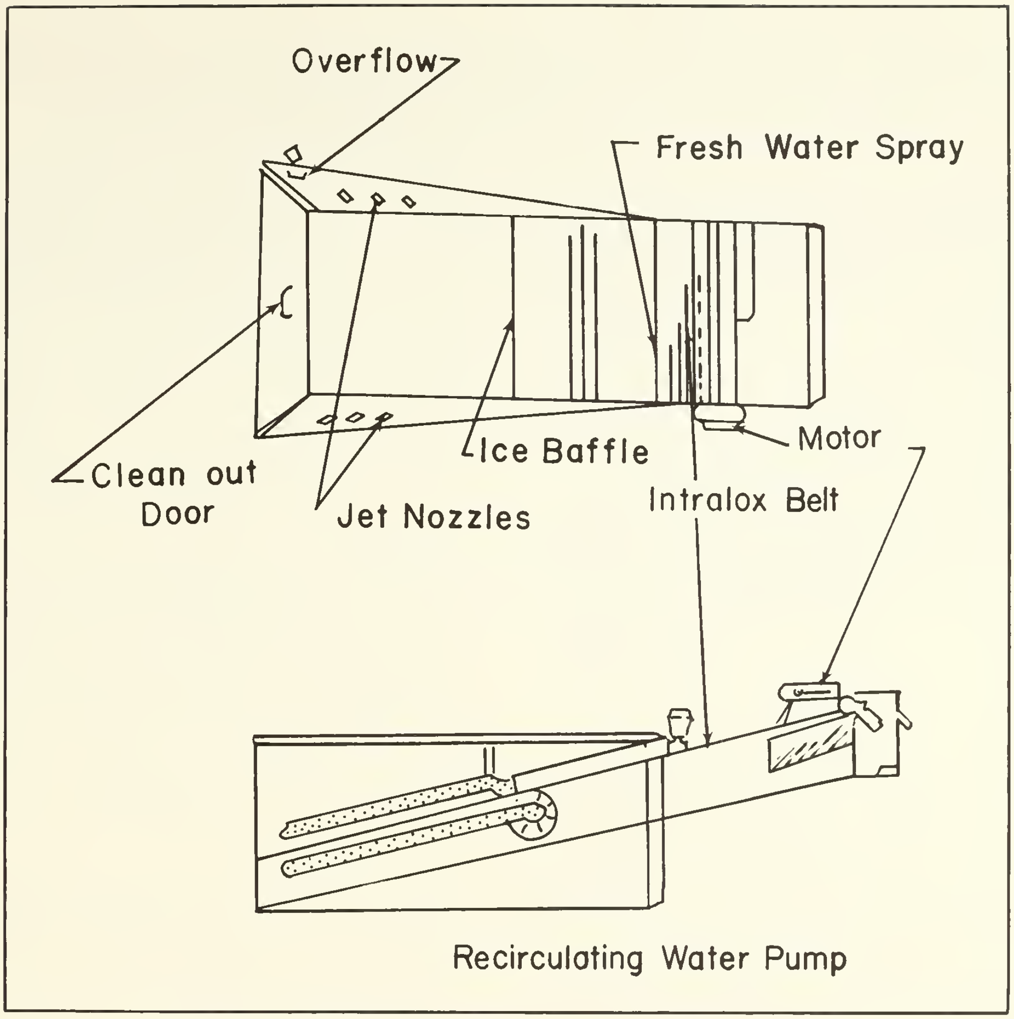
Overflow
Fresh Water Spray
Clean out Door
Jet Nozzles
Ice Baffle
Motor
Intralox Belt
Recirculating Water Pump

Figure 3. An illustration of the wash/receiving tank.

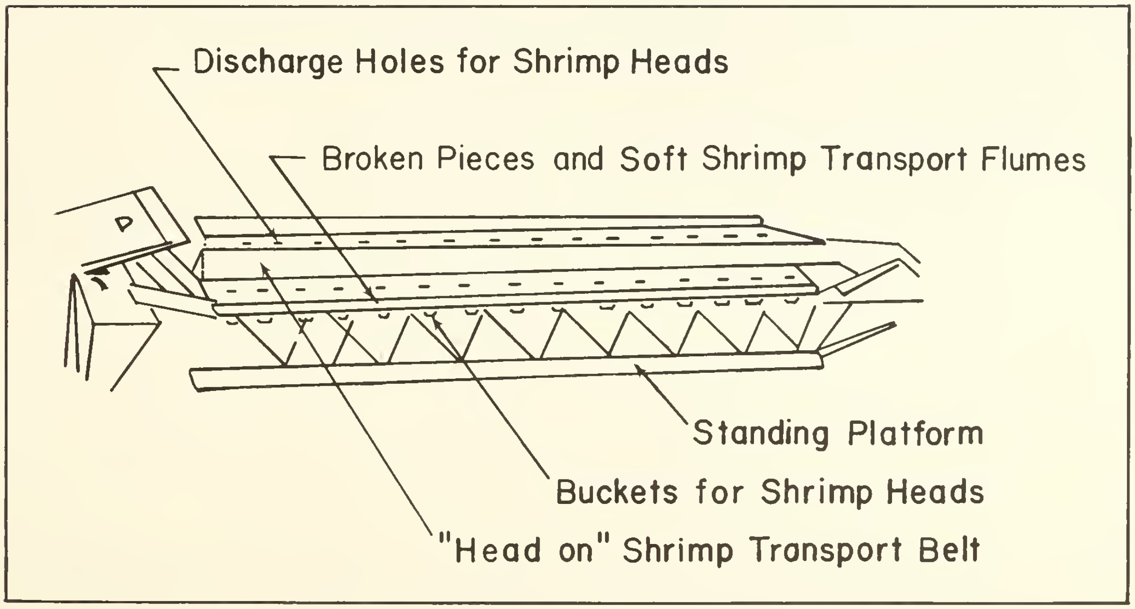
Discharge Holes for Shrimp Heads
Broken Pieces and Soft Shrimp Transport Flumes
Standing Platform
Buckets for Shrimp Heads
"Head on" Shrimp Transport Belt

Figure 4. An illustration of the flume breaking table.

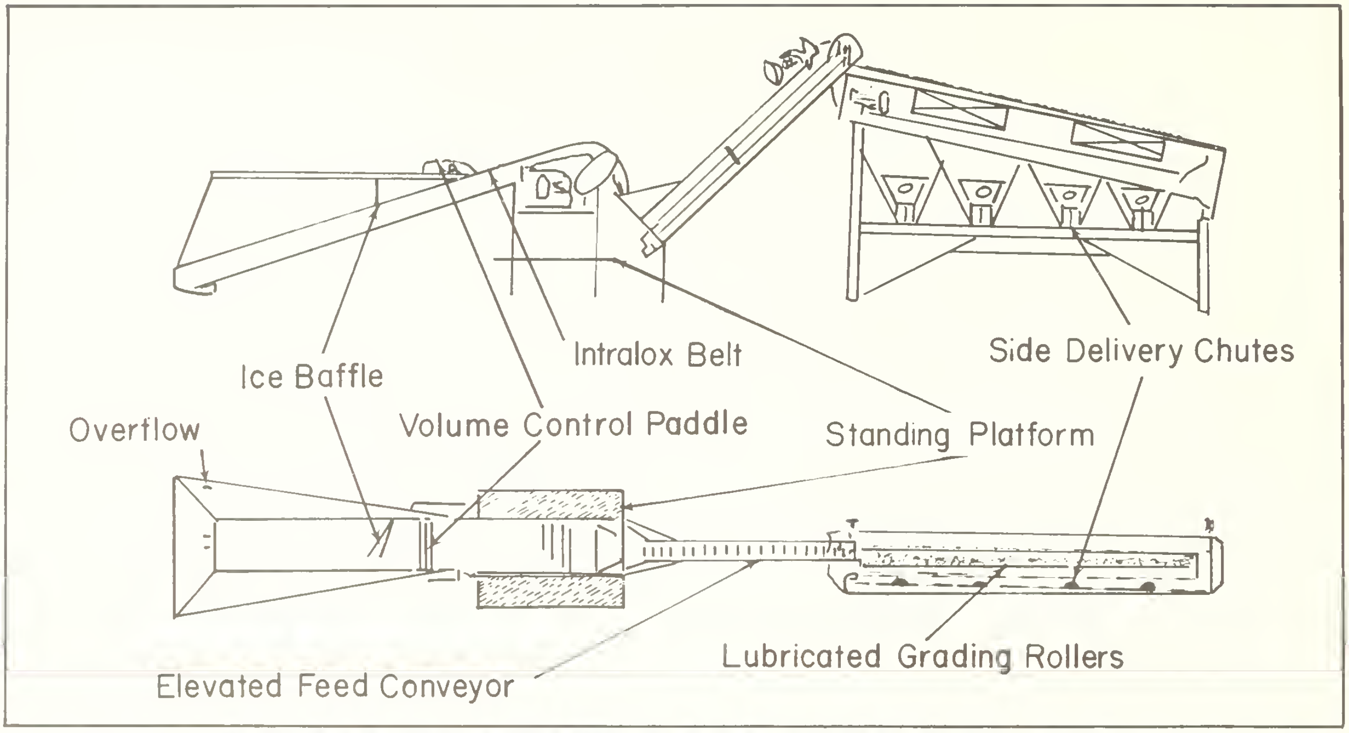

Figure 5. Schematic of one 1,000-pound-per-hour grader and receiving tank.

laminated cardboard boxes are placed 10 to a master carton. Each 13.25 by 11.75 by 16.375-inch corrugated carton is loaded on to a galvanized steel freezer cart that holds 22 cartons or 1,100 pounds of shrimp [3]. That portion of the plant floor where the weighing and packing occurs can be seen in Figure 2.

Blast Freezing

Once the shrimp tails are boxed, cartoned, and loaded onto the freezer carts, each cart is pushed into a small 15 by 15-foot galvanized steel-sided blast freezer. The daily processed shrimp are typically kept overnight in the freon-activated blast freezer, where as many as 22,000 pounds of tails can be exposed to surface temperatures as low as -40°F [1]. The freezer, however, has the capacity to freeze a maximum of 14,400 pounds of tails to internal temperatures of -10° to 0°F in a 12-hour period. After verification of the blast freezer's room temperature, the shrimp are removed three carts at a time.

Glazing

The cartons of frozen shrimp removed from the blast freezer are opened. At this point, each cart is led to a conveyor-belted glazing system where open shrimp boxes are placed on the 14-foot conveyor belt. The belt carries each box under a four-nozzle, preset, regulated spray that coats the frozen shrimp with a thin layer of water, which is immediately turned into a moisture sealing glaze [3]. After passing boxed shrimp under the spray, the belt deposits each box at a small collecting table. Here the boxes are closed, turned over, recartoned, and double strapped with special plastic bands. The strapped cartons are then stacked on wooden pallets.

This whole conveyor belt, nozzle, and strapping system can be purchased through a custom manufacturer, or as usually the case, be built by a local machinist at lower cost. This study assumed use of the higher-cost custom manufactured system because the availability of a local machinist and needed equipment is not assured. Location of the glazing belt in the model plant is shown in Figure 2.

Storage Freezing

Storage freezing of the shrimp tails is the last phase in the processing of green headless shrimp. An electric forklift is used to place 1,750-pound loaded pallets into a large storage freezer for temporary or long term storage.

The storage freezer is a galvanized-steel-walled, double-insulated, and freon-activated system [1] capable of maintaining 690,000 pounds of processed tails at approximately 0°F surface temperature. Dimensions of the freezer are 70 feet long by 36 feet wide, with a 25-foot ceiling. The storage freezer's volume of space to volume of boxed shrimp tails is a three to one ratio [3]. Holding capacity for the storage freezer was based upon the ability to store 8 weeks processing at maximum output. The storage freezer's location within the plant is shown in Figure 2.

Estimated Investment Requirements and Annual Costs for Two Scenarios of a Model Plant

Investment Requirements

Initial investment requirements consisted of equipment and facility needs discussed previously and listed in Appendix Table 2. Investment estimates do not include harvesting equipment, because it was assumed that processing does not include harvesting. Initial investment estimates for the given plant are presented in Table 2.

Land and building costs for Scenarios I and II comprise 47.7 percent and 45.7 percent, respectively, of total investment. The blast and storage freezing equipment was the same for both scenarios, accounting for 23.4 percent and 28 percent, respectively, of total investment. All other required investment items accounted for 28.9 and 26.3 percent of total investment for Scenarios I and II, respectively, with no item accounting for more than 7.0 percent for Scenario I or 8.5 percent for Scenario II.

Annual Ownership Costs

Ownership costs consist of depreciation, interest, taxes, and insurance. These costs occur whether the asset is used or not, and are fixed in the short run. Annual ownership costs are obtained by "annualizing" total ownership costs.

Depreciation

Depreciation of an item is the non-cash expense used to reflect the loss in value of an asset from age, wear, tear, and obsolescence. Depreciation of an asset can be calculated by several methods. The straight-line method was deemed most appropriate for this study. That method involves subtracting the salvage value from the item's initial cost, then dividing the resulting amount by the useful life of the item. In this study, all durable items were assumed to have zero salvage value.

In determining the depreciation cost of the building, a useful life of 30 years was assumed. Considering that the building consists of a thick slab floor, rustproof metal siding, and steel beams every 20 feet, along with the level of maintenance that is generally provided to existing shrimp plants, a 30-year estimate was not considered excessive. Depreciation cost for each piece of equipment was estimated, based on useful life data obtained from manufacturers and supported by interviews with an existing processor (Appendix Table 2). Detailed depreciation costs are

Table 2. Estimated investment requirements and percentage of initial cost, by specific item, for a synthesized shrimp processing plant, two operating scenarios, Mississippi Gulf Coast, 1986.

Item	Scenario I		Scenario II	
	($)	(%)	($)	(%)
Land[a]	120,000	13.3	35,000	4.6
Building	310,000	34.4	310,000	41.1
Breaking equipment[b]	57,164	6.3	57,164	7.6
Grading equipment[c]	63,236	7.0	63,236	8.4
Weighing & packing equipment[d]	7,500	.8	7,500	1.0
Blast freezing equipment[e]	98,612	10.9	98,612	13.1
Glazing & strapping equipment[f]	18,000	2.0	18,000	2.4
Icemaking equipment[g]	18,750	2.1	18,750	2.5
Forklift	28,000	3.1	28,000	3.7
Storage freezer	112,847	12.5	112,847	15.0
Office equipment	11,325	1.2	11,325	1.5
Miscellaneous[h]	12,000	1.3	12,000	1.6
Total	857,434	100.0	772,434	100.0

[a] Includes $8,967 for a waste water line connecting the Scenario II plant to the bay.

[b] Consists of two ice baffles and one flume system.

[c] Consists of two graders.

[d] Consists of three packing tables and six scales.

[e] Consists of blast freezer and 26 freezer carts.

[f] Consists of strapping machine and glazing belt.

[g] Thirty percent of initial investment for icemaking equipment consisting of ice maker and ice conveyor, goes into the processing of shrimp, the other 70 percent is allocated to hauling cost.

[h] Includes minor items of equipment, licenses, permits, and hookup for utilities.

Table 3. Estimated annual ownership costs, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

Item	Scenario I	Scenario II
	($)	
Building depreciation	10,333	10,333
Equipment depreciation[a]	35,303	35,303
Waste water line depreciation		448
Insurance	10,220	10,220
Interest on investment	58,646	48,984
County taxes	30,363	21,155
Municipal taxes	9,632	8,777
Total annual ownership costs	154,497	135,220

[a] Seventy percent of depreciation and interest on icemaking equipment shown in Appendix Table 3 was charged to hauling costs.

included in Appendix Table 3. A summary of depreciation costs is presented in Table 3.

Insurance

Insurance coverage for the equipment and building consisted of fire, vandalism, and extended coverage. In Mississippi, actual rates for each type of coverage were set by the state rating bureau. The rates used to determine total insurance costs added to $2.67 per $100 on 80 percent of initial cost of buildings and equipment. Annual insurance costs for the building and all equipment are included in Table 3.

Interest

Interest was charged at a rate of 12 percent on one-half the initial investment in depreciable items such as buildings and equipment. Interest of 12 percent was also charged on the full value of land. Interest costs for both processing plant scenarios are included in Table 3.

Taxes

Both municipal and county taxes for the model plant were based on rates applicable to the coastal region. Millage rates used for county and city taxes were 73.83 and 67.12 mills, respectively. Millage rates were applied to 15 percent of initial value of land and one-half initial value of buildings and equipment. Inventory tax was based on 6 weeks production at capacity for Scenario I and 4 weeks maximum production for Scenario II. Estimated municipal and county property taxes for both processing plant scenarios are included in Table 3.

Annual Operating Costs for Scenario I

Annual operating costs arise from the actual operation of a given enterprise. Operating costs for this model plant included labor, utilities, repairs and maintenance, supplies, and interest on operating capital.

Labor Costs

Estimates of labor requirements were based upon the output level of the model plant and the equipment necessary to provide that output level. The estimated number of employees needed to operate the model plant at capacity were based on manufacturers' recommendations, and interviews with management of existing shrimp processing plants. Data obtained from interviews were consistent with results of time-motion studies presented in Appendix Table 10. Employee requirements, with corresponding hourly wage, are presented by job classification in Appendix Table 5. Labor cost, except for the president (plant manager) and head breakers, are presented on an hourly wage basis. Head breakers are typically paid on a "piece" basis. Hourly performance and wage rates were based upon interviews and supported by time-motion studies. The president's salary was based upon the minimum income necessary to retain his employment. It was assumed that the plant owner functions as president, comptroller, marketing director, and plant manager.

Total annual salary costs associated with each job classification are presented in Appendix Table 6. Fringe benefits for all labor operating on the processing floor was assumed to be 15 percent, while fringe benefits for management and non-floor operators was assumed at 20 percent. Total labor costs for the processing plant are summarized in Table 4.

Utilities

Electricity Costs. Electricity costs for the model plant were based upon the electrical requirement of each piece of processing equipment's electric motor, and the electricity required for plant lighting.

Electricity costs for each piece of processing equipment were calculated based upon its motor's horsepower. Once the horsepower ratings for all equipment involved were obtained from the manufacturer, each rating was placed into the following equa-

Table 4. Estimated total labor costs, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

Operation	Scenario I	Scenario II
	($)	
Receiving and breaking	598,688	192,685
Grading and packing	90,160	25,760
Blast freezing and glazing	33,810	9,660
Packing and storage	45,080	12,880
Salaried and office personnel	173,796	114,528
Total	941,574	355,513

tion to determine the electricity costs for that particular motor [6]:

$$E = .746 \times HP \times C \times N \times 100/Eff.$$

where

E = electrical cost of motor
HP = horsepower of motor
C = electricity rate in dollars per kwh
N = number of operating hours
Eff. = normal full-load efficiency (%) of original motor

To derive annual electricity costs for each motor, total operating hours per year were used for number of operating hours (N). The efficiency percentage, which varied for each horsepower rating, was obtained from Graingers net price motorbook catalog [6]. The electricity rate used for this study was 7.5 cents per kwh, the average monthly rate charged by Mississippi Power Company to its business customers in the Biloxi, MS, area. Data used for estimating electrical costs of motors are presented in Appendix Table 7. Estimated annual electricity costs for freezers are included in Appendix Table 8.

Estimates of annual lighting costs were based upon the average electrical requirements for a comparable plant size. These electrical requirements for plant lighting amounted to 40 watts per square foot of floor space per month. Total annual electricity costs for the model plant are included in Table 5.

Water Costs. Processing green headless shrimp requires large quantities of water. The greatest portion of water required by the model plant was for rinsing and moving shrimp through the flume trough and baffle tanks. The graders also used a significant amount of water for their overhead spray component. The estimated daily requirements of water per piece of equipment are presented in Appendix Table 9.

Total annual costs of water used by the model processing plant also included water for cleanup. The estimate for water cost was based upon rates charged by Biloxi City Water Association. The rates for commercial water use in Biloxi were $1.00 per 1,000 gallons drinking water and $1.50 per 1,000 gallons sewage. Total annual water costs for this plant are included in Table 5.

Telephone Costs. Telephone costs were based on a two-line, five-phone, intercom system, with an outgoing WATS line and an incoming 800-number covering Mississippi, Florida, Alabama, Georgia, and parts of Texas. Telephone rates used were based on service provided by South Central Bell and AT&T. The South Central Bell rate was $157.94 per month. Total costs of assumed AT&T service consisted of $42.80 per month for WATS service, and long-distance service charge at the rates of 28¢ per minute for the first 15 hours and 25¢ per minute for the next 25 hours. Under assumed long-distance usage, total telephone costs were estimated to be $600 per month when the plant was operating at capacity. During months when the plant operated at less than capacity, the portion of telephone cost associated with actual usage was adjusted proportionately. Total annual telephone cost is included in Table 5.

Table 5. Estimated annual operating costs, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

Item	Scenarios I	Scenarios II
	($)	($)
Labor	941,574	355,513
Utilities		
Electricity[a]	40,765	27,650
Water	1,363	361
Telephone	6,315	5,513
Repairs and maintenance	17,638	5,324
Supplies and services		
Packaging	36,382	10,036
Transporting	51,746	14,471
Washdown	42	21
Miscellaneous	10,000	4,687
Waste disposal	3,336	1,572
Subtotal	1,109,163	425,148
Interest on operating capital	162,094	178,955
Total annual operating cost	1,271,257	604,103

[a] Seventy percent of costs associated with icemaking were charged to hauling costs.

Repairs and Maintenance Costs

Annual repairs and maintenance costs for all equipment and the building were obtained from interviews with equipment dealers, interviews with existing plant managers, and related publications concerning seafood processing [4]. Repairs and maintenance costs were converted to a percentage of the purchase price of the asset (Appendix Table 2).

The estimates of repairs and maintenance costs for this study, presented in Appendix Table 3, may seem unrealistically low for some equipment items. However, all labor costs involved in repair and maintenance were included in the plant repairman's salary costs. Maintenance costs for the building itself were estimated to be only one percent of purchase price. Total repairs and maintenance costs for the model processing plant are included in Table 5.

Supplies and Services

Additional necessary items required in the processing of green headless shrimp consist of packaging and transporting supplies, washdown equipment, and miscellaneous supplies and services.

Packaging supplies consist of the boxes, cartons, and straps necessary to prepare and contain the processed shrimp in frozen storage.

Transport supplies, those items used to contain the shrimp for movement within the processing plant, include wooden pallets for loading and storing, and the large perforated collecting baskets used in grading.

Washdown supply costs consist of two replacement water hoses with nozzles.

Miscellaneous supplies include brooms, shovels, hand brushes, cleanser, chlorine, paper towels, rakes, and general overhead such as postage. Estimated costs of supplies and services are included in Table 5.

Waste Disposal Costs

The annual costs associated with waste disposal were the charges for hauling away solid wastes collected daily in dumpsters, and the monthly rent on dumpsters. The per-load hauling charge was $28 and rent on the dumpster amounted to $75 per month. Waste disposal costs, which are included in Table 5, were based on the use of one dumpster, which would be hauled away every other day.

Interest on Operating Capital

Interest on annual operating capital was charged at a rate of 12 percent on one-ninth of the plant's total operating cost, plus the average value of frozen inventory. Average inventory for the model plant was estimated to be 40 percent of freezer storage capacity. Average value of inventory was obtained by multiplying the average inventory by the 5-year average wholesale price for 30-35 count marine shrimp tails ($4.44 per pound) [14]. Interest costs are shown in Table 5.

Annual Operating Costs for Scenario II

Since most of the operating costs were calculated in the same manner for both scenarios, this portion of the study primarily explains the differences in costs for the two operating scenarios.

Labor Costs

Labor costs for Scenario II are not proportionately less than for Scenario I, because some labor is required year-round. In addition to the work of the president (who also acts as plant manager and salesman), some maintenance, loading out frozen shrimp, and secretarial duties are required year round. It was assumed that these additional duties would be performed by the plant maintenance man, who operated the forklift, and a single secretary assisting in the office. Maintaining freezer equipment and loading of shrimp required 40 hours per week from the maintenance man while the secretary worked part-time 20 hours per week at the normal hourly rates as presented in Appendix Table 5.

Utilities

Electricity costs for each piece of equipment under Scenario II, excluding storage freezer, were calculated using the same formula as used for Scenario I. The only difference in the result was in the number of operating hours (N), which were proportionately less than in Scenario I for every piece of equipment except the storage freezer. The storage freezer was operated year round in order to make available a constant supply of processed shrimp to regular customers throughout the year. Electricity costs per item are included in Appendix Table 8.

Water costs for Scenario II were proportionately lower than water costs for Scenario I. Less water was required because virtually all water use occurred during the operation of processing equipment and cleanup. Thus, water use and cost for Scenario II were 27 percent of those of Scenario I.

Telephone costs for Scenario II were only slightly less than those for Scenario I. For the plant to continue marketing its stored product for a full year, local service and WATS service were maintained year

Table 6. Estimated annual costs, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

Item	Scenario	
	I	II
	($)	
ANNUAL OWNERSHIP COSTS		
Depreciation	45,636	46,084
Insurance	10,220	10,220
Interest	58,646	48,984
Taxes	39,995	29,932
Subtotal	154,497	135,220
ANNUAL OPERATING COSTS		
Labor	941,574	355,513
Utilities		
Electricity	40,765	27,650
Water	1,363	361
Telephone	6,315	5,513
Repairs and maintenance	17,638	5,324
Supplies and services		
Packaging	36,382	10,036
Transporting	51,747	14,471
Washdown	42	21
Miscellaneous	10,000	4,687
Waste disposal	3,336	1,572
Subtotal	1,109,162	425,148
Interest on operating capital	162,094	178,955
Total annual operating costs	1,271,256	604,103
Total costs	1,425,753	739,323
Total pounds processed	2,505,600	691,200
Cost per pound	.57	1.07

round. The portion of long distance costs required for marketing the product were the same for both scenarios.

Repair and Maintenance Costs

Since no information was available concerning annual repair and maintenance estimates for equipment used only 2 months of the year, a percentage of the repair cost for Scenario I was estimated for Scenario II. Some amount of deterioration occurs to equipment and buildings whether they are used or not. In this case, it was assumed that repair and maintenance costs for Scenario II amounted to 30 percent of the repair costs for Scenario I.

Supplies and Services Costs

Supplies and services costs for Scenario II were based upon the proportionate 27 percent of costs of supplies for Scenario I. This proportionate percentage was used to estimate costs of all supplies and services excluding packaging costs. Packaging supply costs were based on packaging supplies necessary for packing the estimated output for Scenario II. Thus, annual supplies and service costs for Scenario II were approximately 27 percent of the costs for Scenario I.

Interest on Operating Capital

Annual interest on operating capital was charged at a rate of 12 percent on one-half of total annual operating cost. Interest was also charged on average inventory, which was assumed to be one-half of the maximum storage capacity for a period of 10 months.

Annual Cost Analysis

Total annual costs of processing freshwater shrimp under Scenarios I and II were $1,425,753 and $739,323, respectively (Table 6). Given the processing volumes of Scenarios I and II of 2,505,600 and 691,200 pounds, respectively, costs per pound of processing green headless shrimp for Scenarios I and II were $.57 and $1.07, respectively. Per-pound cost of processing shrimp only 2 months of the year (Scenario II) is almost twice as much as for the plant operating 9 months of the year (Scenario I). The major components of the cost are shown in cents per pound in Table 7.

Ownership costs for Scenario I made up only 10.82 percent of the total annual cost, whereas ownership costs under Scenario II represented 18.29 percent of total cost (Table 8). The reason for this is that owner-

Table 7. Estimated annual cost components expressed in cents per pound for a synthesized shrimp processing plant, two operating scenarios, Mississippi Gulf Coast, 1986.

Item	Scenario I	Scenario II
	(¢/lb)	
ANNUAL OWNERSHIP COSTS		
Depreciation	1.82	6.66
Insurance	.41	1.48
Interest	2.34	7.00
Taxes	1.60	4.30
Subtotal	6.17	19.44
ANNUAL OPERATING COSTS		
Labor	37.58	51.40
Utilities		
Electricity	1.63	4.00
Water	.05	.05
Telephone	.25	.80
Repairs and maintenance	.70	.77
Supplies and services		
Packaging	1.45	1.45
Transporting	2.10	2.09
Washdown	0.00	0.00
Miscellaneous	.40	.68
Fuel costs		
Waste disposal	.13	.13
Subtotal	44.30	61 .40
Interest on operating capital	6.47	25.90
Total annual operating costs	50.77	87.30
Total cost per pound	57.00	107.00

Table 8. Estimated annual cost components expressed as a percentage of total costs for a synthesized shrimp processing plant, two operating scenarios, Mississippi Gulf Coast, 1986.

Item	Scenario I	Scenario II
	(%)	
ANNUAL OWNERSHIP COSTS		
Depreciation	3.20	6.23
Insurance	.72	1.38
Interest	4.10	6.62
Taxes	2.80	4.05
Subtotal	10.82	18.29
ANNUAL OPERATING COSTS		
Labor	66.00	48.10
Utilities		
Electricity	2.86	3.74
Water	.10	.05
Telephone	.44	.75
Repairs and maintenance	1.24	.72
Supplies and services		
Packaging	2.55	1.36
Transporting	3.63	1.96
Washdown	0.00	0.00
Miscellaneous	.70	.63
Waste disposal	.23	.21
Subtotal	77.75	57.57
Interest on operating capital	11.36	24.24
Total annual operating costs	89.11	81.76
Total	100.00	100.00

ship costs are fixed and diminish as a proportion of total costs as plant production increases. Depreciation and interest on investment, combined, made up the major portion of ownership costs for both scenarios, comprising 7.3 percent of total annual costs for Scenario I and 12.85 percent of total annual costs for Scenario II.

Labor cost represented the single greatest component of operating cost for both scenarios, as seen in Table 6. Labor costs for Scenarios I and II amounted to $941,574 and $355,513, respectively. This translates into a labor cost of 37.58 cents per pound for Scenario I and 51.40 cents per pound for Scenario II (Table 7).

Hauling Costs

Two methods for hauling freshwater shrimp from farms to the processing plant were considered: **(1)** hauling ice-packed shrimp on refrigerated trucks (similar to the method commonly used for hauling marine shrimp); and **(2)** live-hauling in aerated freshwater tanks (similar to the method used for hauling catfish). While some data used in deriving ice-packed hauling costs were obtained from marine shrimp processors, methods used in estimating trucking costs of both hauling techniques were based upon data obtained from a previous study on the costs of live-hauling catfish [7]. Precautions and management practices necessary to deliver live-hauled fish in good health were assumed to be appropriate for live-hauling shrimp [9].

The method of harvesting freshwater shrimp was described in a previous MAFES report [2]. Basically, the freshwater shrimp ponds are drained and the shrimp collected in half-inch mesh cages placed under the drain pipe in a harvest basin. For this study, it was assumed that the hauling trucks would be at the harvest site when harvesting begins, so that stress to the shrimp would be minimized. In the case of live-hauling, each cage load of shrimp would be removed from the basin, weighed, and placed directly into the aerated tanks of the live-haul trucks. In the case of ice-packed hauling, each cage load of shrimp would be placed into an ice bath tank in which the shrimp are chill-killed. Minutes later the chill-killed shrimp would be removed, weighed, and packed in wooden boxes, each containing 105 pounds of shrimp and 50 pounds of ice. The boxes would then be stacked on wooden pallets in the truck to accommodate unloading at the processing plant.

Important factors in determining the total costs for both methods of hauling were trucking and labor costs. Trucking costs depended primarily upon type and size of truck. It was assumed that the size and type of trucks used to haul live catfish in the Delta could be used for both methods of shrimp hauling, but equipped differently; that is, straight flatbed trucks with 270-horsepower engines equipped with five- to seven-speed transmissions and twin rear axles. For live-hauling, it was assumed that each truck would carry four separately designed aerated tanks. It was assumed that the truck used to haul ice-packed shrimp would be equipped with a single refrigerated, insulated box. Initial costs for each type of truck are presented in Table 9.

In order to determine total annual and per-pound costs for each method of hauling, the number of trucks required, the number of miles hauled, and the number of loads hauled for each method must be known. The number of trucks used for each method could be derived if the amount of shrimp carried per load and the load time were known. The carrying capacity for refrigerated trucks, 15,700 pounds live weight, was supplied by marine shrimp processors. Under the assumptions that each truck would average only 40 miles per hour on a paved road and would travel an average one-way distance of 50 miles, time required per load was such that only two trips per day could be made.

Data on carrying capacity for live-haul trucks were based on shrimp-to-water density tests conducted at Mississippi State University. (The unpublished preliminary tests were not replicated, thus were not

Table 9. Estimated initial investment per truck for live-hauling and ice-packed hauling of freshwater shrimp, 1986.

Item	Live-haul Truck	Refrigerated Truck
	($)	
Truck[a]	62,500	62,500
20 ft. bed and MD-150 refrigerator[b]		17,700
Aerator motor[c]	1,500	
Aerator blower	1,500	
Four (4x5x8) tanks	8,500	
Total	74,000	80,200

[a] Truck cost obtained from local dealers.

[b] Insulated bed and refrigeration requirements and prices obtained from Gulf City Body Inc., Mobile AL.

[c] Aerator and livehaul equipment requirements and prices supplied by Delta Pride Catfish Processors, Indianola, MS.

conclusive.) The results of these tests suggest that it was reasonable to haul 4,000 pounds of live shrimp per load up to 100 miles one way. However, as in the previous case, the average trip was assumed to be 50 miles one way. Time per load for live-hauling shrimp (7.08 hours per load) was derived by substituting appropriate data into a formula used in a previous catfish live-haul study [7]. Based upon this time per load, along with the above stated capacity of each load, and daily processing capacity (32,000 pounds live weight), the number of trucks needed for the ice-packed and live-haul methods were three and four trucks, respectively. The three refrigerated trucks (one truck would be required for hauling ice) were able to handle daily processing capacity with one trip per day each. Daily processing capacity required four live-haul trucks, each making two trips per day.

From the above information, number of trips per day for each method of hauling was totaled so as to provide the total number of trips annually for each method. Since each trip was assumed to be an average of 50 miles one way (average distance from shrimp ponds to the processing plant), total number of trips traveled by each method of hauling was derived.

Annual Ownership Costs

Annual ownership costs for both methods of hauling freshwater shrimp consisted of depreciation, interest on investment, insurance, and taxes on all investment items. Depreciable items for the live-haul method of shrimp transport consisted solely of trucks and associated equipment. In the case of hauling shrimp packed in ice on refrigerated trucks, a portion of the cost of the icemaking system in the processing plant was allocated to hauling. Based on ice requirements for hauling and processing, it was assumed that 70 percent of total annual costs of the icemaking system (icemaker and conveying system) was allocated to hauling costs. Initial investment costs for a 10-ton icemaker and conveying system are presented in Appendix Table 2. Annual ownership costs for ice-packed hauling were the same for both processing plant scenarios. Hauling costs are summarized in Table 10.

Depreciation and Interest

Depreciation costs were derived by the straight-line method. Salvage value of trucks for both methods of hauling was assumed to be 10 percent of initial cost with an 8-year useful life. Salvage value for the icemaking equipment for the ice-packed method of hauling was assumed to be zero with a useful life of 10 years. Interest on average investment for both methods of hauling shrimp was based on a rate of 12 percent for all investment items.

Insurance

Insurance costs of trucks for both hauling methods were derived by adjusting for inflation the insurance

Table 10. Estimated total annual costs and costs per pound of two methods of hauling freshwater shrimp 50 miles one-way from farms to two synthesized processing plants, 1986.

Item	Refrigerated Trucks Scenario I	Refrigerated Trucks Scenario II	Live-haul Trucks[a]
	($)		
OWNERSHIP COSTS			
Depreciation	31,375	31,375	33,300
Interest on investment	18,504	18,504	19,536
Insurance	2,053	2,053	1,785
Taxes	2,325	2,325	1,621
Subtotal	54,257	54,257	56,242
OPERATING COSTS			
Labor	49,392	14,112	18,816
Electricity	2,571	709	0
Water	304	84	230
Repairs	6,709	1,880	3,264
Fuel	11,733	3,168	8,448
Supplies	40,061	11,261	0
Subtotal	110,770	31,215	30,758
Interest on operating capital	1,477	1,873	1,845
Total annual cost	166,504	87,345	88,845
Total quantity hauled (lb)	5,568,000	1,536,000	1,536,000
Cost per pound ($)	.0299	.0568	.0578

[a] Cost of live-hauling freshwater shrimp is the same for both scenarios.

costs reported in a 1984 study of costs of live-hauling catfish [7]. Seventy percent of the insurance cost of ice-making equipment in the processing plant was included in ice-packed hauling cost. Total annual insurance costs for both hauling methods are included in Table 10.

Taxes

Taxes on trucks for both methods of hauling were based on rates representative of the study area. Taxes on icemaking equipment for the ice-packed hauling method were 70 percent of the municipal and county taxes previously derived for icemaking equipment.

Annual Operating Costs

The costs arising from the actual operation of hauling equipment included labor, electricity, water, repairs, fuel, and supplies, with electricity and supply costs arising only with the ice-packed method of hauling. Unlike ownership costs, operating costs varied with output, resulting in different operating costs for the ice-packed method of hauling for the two plant scenarios. A summary of operating costs is included in Table 10.

Labor Costs

Labor costs for both methods of hauling consisted solely of driver labor, which was based on a rate of $7.00 per hour with time and a half for overtime, plus 20 percent for fringe benefits. It was assumed that drivers worked 10 hours per day during the months when the plant was operating at capacity. It was also assumed that any assistance needed by the harvesting crew in icing shrimp for the ice-packed hauling method was performed by the truck drivers.

Electricity Costs

Electricity costs for the ice-packed hauling method were based upon the electrical requirements of the processing plants' icemaking equipment. The electricity cost for the icemaking equipment was based upon its motor's electrical requirements. It was assumed that 70 percent of these costs were used in the production of ice for shrimp hauling, as presented in Table 10. No electricity costs were assumed for the live-hauling method, since no ice was required.

Water Costs

Water costs for the ice-packed method of shrimp hauling were derived from the water used in the plant's icemaker for making the ice required for icing shrimp in refrigerated trucks. Annual water costs for live-hauling consisted of the water required for filling aerated tanks. All water costs were based upon a rate of $1.00 per 1,000 gallons–the rate charged by Biloxi City Water Association.

Repairs and Maintenance Costs

Repairs and maintenance costs for trucks used in both hauling methods amounted to 8.5¢ per mile. Estimates of repair and maintenance costs of icemaking equipment, which were obtained from a major supplier, amounted to 50 percent of its initial cost spread over a useful life of 10 years. Seventy percent of these costs were allocated to hauling costs.

Fuel Costs

Diesel fuel costs for both methods of hauling were based on a highway fuel consumption rate of 5 miles per gallon, plus 2 gallons per trip for loading and unloading. Price of diesel fuel was assumed to be $1.00 per gallon.

Supplies

The only additional items required in the hauling of freshwater shrimp were the wooden boxes used for packing and loading iced shrimp in refrigerated trucks and wooden pallets used to load and unload packed boxes of iced shrimp. Total annual costs for wooden boxes were based on $2.25 per box, each having an average life of three trips. The cost for pallets was based on a price of $7.25 per pallet. It was estimated that 40 pallets were required annually.

Interest on Operating Capital

For both scenarios interest on operating capital was charged at an annual rate of 12 percent. Interest was charged on one-ninth of the total operating cost for Scenario I, and on one-half the total operating cost for Scenario II.

Hauling Cost Analysis

Under Scenario I, it was assumed that the synthesized plant would process marine shrimp 7 months and freshwater shrimp for 2 months, and that all shrimp were hauled in refrigerated trucks. Total annual hauling cost for Scenario I amounted to $166,504, or approximately 3¢ per pound (Table 10).

Under Scenario II, the synthesized plant operated for only 2 months, processing only freshwater shrimp. The freshwater shrimp could be hauled in either refrigerated trucks or in live-haul trucks. Total annual hauling costs amounted to $87,345 if refrigerated trucks were used and $88,845 if live-haul trucks were used. Thus, cost per pound for hauling under Scenario II was 5.7¢ for hauling ice-packed shrimp in refrigerated trucks, and 5.8¢ for live-hauling shrimp (Table 10).

Summary, Conclusions, and Limitations

The continued decline in domestic landings of marine shrimp and the increase in consumption have resulted in large quantities of imported shrimp by the United States. The increasing consumption and declining domestic landings suggest that a potential market may exist for farm-raised freshwater shrimp (*Macrobrachium rosenbergii*). Presently, farmers in Mississippi and throughout the United States are interested in the economic feasibility of producing and marketing such a product.

Recent experiments in production, processing, and storage of freshwater shrimp have been encouraging, as have preliminary tests of consumer acceptance. But no assessment of assembly or processing costs has been published. If the economic feasibility of freshwater shrimp production in Mississippi is to be adequately assessed, an estimate of processing costs is required.

The synthetic firm approach was used in this study to estimate costs of assembling and processing freshwater shrimp in the Gulf Coast area of Mississippi. Data for the study were obtained from personal interviews with processors and extension personnel, manufacturers' specifications, appropriate dealer estimates, and limited time-motion studies.

A plant and operation capable of assembling and processing 14,400 pounds per day of green headless shrimp were synthesized. Space requirements of equipment and personnel necessary to efficiently process those shrimp were based upon currently used technology. A plant capable of this daily capacity was formulated based on the necessity to process and store 691,200 pounds of shrimp tails within the 2-month harvest period for freshwater shrimp. Processing costs were estimated for the synthesized plant operating under two scenarios: 9 months of operation (Scenario I) and 2 months of operation (Scenario II).

Except for land cost, the estimated initial investments for both scenarios of the model plant were the same. Equipment costs represented the largest percentage of total investment, with 52 percent for Scenario I and 54 percent for Scenario II. Freezer equipment alone comprised 23 and 28 percent of total investment for Scenarios I and II, respectively. The remaining major items, building and land combined, comprised 48 and 46 percent of total investment for Scenarios I and II, respectively.

Annual ownership costs for the 9- and 2-month scenarios were $154,497 and $135,220, respectively. Annual operating costs amounted to $1,271,257 for Scenario I and $604,103 for Scenario II. Total annual costs for Scenarios I and II were $1,425,753 and $739,323, respectively. Costs per pound of processing shrimp were $.57 for Scenario I and $1.07 for Scenario II.

The economic engineering approach was also used in estimating the costs for hauling freshwater shrimp. Data and methodology used in developing these cost estimates were partly obtained from a previous study concerned with live-hauling catfish [7] and from interviews with equipment suppliers and commercial shrimp processors.

Costs were estimated for two methods of hauling shrimp: hauling in refrigerated trucks, and live-hauling. Estimated costs for hauling shrimp in refrigerated trucks were 3¢ and 5.7¢ per pound, respectively, for Scenarios I and II. Cost of hauling in live-haul trucks for Scenario II was 5.8¢ per pound.

Conclusions

Based on the results of this study, costs of processing freshwater shrimp in a plant that also processes marine shrimp (Scenario I) were much lower than for the plant built solely for processing freshwater shrimp (Scenario II). Costs of hauling freshwater shrimp were also much lower for Scenario I because the refrigerated trucks were used over a longer period of time. Costs of hauling freshwater shrimp to a plant operating for 2 months (Scenario II) were essentially the same for both hauling methods studied.

Limitations

Only one product form was studied–frozen, green headless shrimp. Cost estimates were limited to assembly and processing costs. No harvesting, distribution, or marketing charges (except for manager's salary and telephone charges) were included in the costs for processing shrimp. Thus, some additional marketing research is needed before the economic feasibility of freshwater shrimp production can be adequately assessed.

Costs were formulated utilizing the industry's accepted processing methods and technologies, which provide an initial estimate of the cost to process green headless shrimp. While there may be lower cost alternatives, none were discovered in this research. Also, this analysis contains a shortcoming inherent in any synthesis of an operation where processing volume is specified at the outset: such analysis precludes a look at economies of scale.

Quantity of shrimp hauled per load is critical in determining cost of live-hauling. The hauling density used in estimating costs was based on unreplicated tests. Further tests are needed to evaluate possible densities for live-hauling over various distances.

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Appendix

Appendix Table 1. Monthly landings of gulf marine shrimp, annual and 5-year averages, Northern Gulf region, 1981-1985.

	Year					5-Year	
Month	1981	1982	1983	1984	1985	Avg.	Monthly Pct.
	(1,000 lb)						
January	3,686	4,282	4,356	3,587	7,909	4,764	3
February	1,694	3,242	2,755	2,610	3,847	2,830	2
March	3,594	2,766	2,616	2,687	3,812	3,095	2
April	4,679	2,848	3,417	3,409	4,442	3,759	3
May	20,202	16,781	10,920	16,827	21,475	17,241	12
June	27,504	23,019	22,466	28,772	27,008	25,772	17
July	24,026	17,305	17,253	22,534	20,256	20,274	14
August	23,897	13,739	14,500	18,556	17,854	17,709	12
September	17,087	12,365	12,064	13,620	14,166	13,860	9
October	18,943	16,228	15,386	18,860	17,816	17,403	12
November	16,331	12,548	12,568	12,527	14,837	13,762	9
December	9,748	7,374	8,116	11,173	–	9,103	6[a]
Total						149,572	101[b]

[a] Based upon 4-year average.

[b] Does not add to 100 percent because of rounding.

Source: USDC, NOAA, NMFS.

Appendix Table 2. Data used for estimating annual ownership cost for processing and hauling freshwater shrimp, Mississippi Gulf Coast, 1986.

Item	Number	Estimated Cost New	Annual Repairs	Estimated Life
		($/item)	(% of new cost)	(yr)
Ice baffle	2	14,852	1.3	20
Flume system	1	27,460	2.4	20
Grader A	1	28,420	1.2	20
Grader AA	1	34,816	1.2	20
Glazing belt	1	6,000	5.0	20
Packing tables	3	500		15
Freezer carts	26	850		15
Scales	6	1,000	5.0	5
Forklift	1	28,000	5.0	15
Ice conveyor	1	17,500	5.0	10
Icemaker	1	45,000	5.0	10
Blast freezer	1	76,512	5.0	10
Storage freezer	1	112,847	5.0	10
Strapping machine	1	12,000	2.5	10
Office equipment	*	11,325		10
Truck	2	80,200	3.6	8
Miscellaneous equipment		12,000		10
Building	1	310,000	1.0	30
Land[a]		120,000		
Land[b]		35,000[c]		

* Assorted.

[a] Land cost for Scenario I.

[b] Land cost for Scenario II. Land cost includes $8,967 for a waste water line from the plant to the bay.

[c] Scenario II land price includes installation of liquid effluent release piping.

Appendix Table 3. Estimated annual depreciation, interest on average investment and repair and maintenance costs for all durable assets, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

Item	Depreciation	Interest	Repairs & Maintenance
		($)	
Ice baffle tank	1,485	1,782	393
Flume breaking system	1,373	1,648	654
Grading system equipment	3,162	3,794	787
Glazing system equipment	300	360	300
Packing tables	100	90	
Freezer carts	1,473	1,326	
Electronic scales	1,200	360	300
Electric forklift	1,867	1,680	1,400
Ice conveyor equipment[a]	1,750	1,050	875
10-ton icemaker	4,500	2,700	2,250
Blast freezer equipment	7,651	4,591	3,826
Storage freezer equipment	11,285	6,771	5,642
Strapper equipment	1,200	720	300
Office supplies	1,132	680	
Trucks (diesel)[b]	27,000	15,840	2,958
Miscellaneous equipment	1,200	720	
Building	10,333	18,600	3,100[c]
Land[d]	–	14,400	–
Land[e]	–	3,124	–
Waste water line	448	538	–

[a] Seventy percent of all ice making costs was allocated to hauling costs.

[b] All truck expenses were included in hauling costs.

[c] Repair cost for building was assumed to be only 1 percent annually due to the use of plant labor in making repairs.

[d] Scenario I.

[e] Scenario II.

Appendix Table 4. Estimated number of pieces and cost of office equipment, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

Equipment	Quantity Required	Cost of Item
	(No.)	($)
Executive desk	1	500
Executive chair	1	400
Office manager desk	1	525
Office manager chair	1	400
Secretaries desk	2	525
Secretaries chair	2	250
File cabinet	6	250
Book case	5	150
Guest chair	14	175
Supply cabinet	3	75
Table	5	85
Desk accessory	4	200
Typewriter & stand	3	600
Total		11,325

Appendix Table 5. Estimated number of employees by wage and salary scale, by job classification, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

	Wage and Salary Scales					
	Piece Rate	Dollars/Hour				
Job Classification[a]	17¢/lb.	5.00	6.00	7.00	8.00	10.00
	(no. of employees)					
Supervisor				2		
Office manager					1	
Grader		2				
Weigher & packer		6				
Blast freezer operator		2				
Glazer & strapper		2				
Storage freezer operator		2				
Forklift operator		1				
Repairman						1
Secretary			2			
Head breaker	32					

[a] Duties of more than one classification can be performed by an employee. One example, packers may be required to accompany drivers for loading shrimp on trucks.

Appendix Table 6. Estimated salary and fringe benefit costs, by job classification, two scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

	Scenario					
	I			II		
Job Classification	Salary[a]	Fringe Benefit[b]	Total	Salary[a]	Fringe Benefit	Total
	($)					
President	50,000	10,000	60,000	50,000	10,000	60,000
Floor supervisor	13,720	2,744	16,464	3,920	784	4,704
Office manager	18,560	3,692	22,252	4,480	896	5,376
Grader operator	9,800	1,470	11,270	2,800	420	3,220
Weighing & packing labor	9,800	1,470	11,270	2,800	420	3,220
Blast freezer loader	9,800	1,470	11,270	2,800	420	3,220
Storage freezer loader	9,800	1,470	11,270	2,800	420	3,220
Forklift operator	9,800	1,470	11,270	2,800	420	3,220
Repairman	23,200	4,640	27,840	21,600	4,320	25,920
Secretary full time	13,920	2,784	16,704	8,160	1,632	9,792
Secretary part time	11,760	2,352	14,112	3,360	672	4,032
Head breaker	16,209	2,440	18,709	5,236	785	6,021

[a] Salaries for all employees except president are based upon hourly wage, hours worked, and time-and-a-half overtime. Monthly salaries are higher for most classes of workers under Scenario II because of more overtime.

[b] Fringe benefits refer to social security, unemployment, workmens compensation, hospitalization, and seasonal bonuses.

Appendix Table 7. Estimated number of motors and horsepower, efficiency, and number of operating hours per motor, by item of equipment, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

Item	Number of Motors	H.P. of Motor	Efficiency of Motor	Number of Operating Hours Scenario	
				I	II
			(%)		
Ice baffle 1	1	.75	75.3	1,740	480
Ice baffle 2	1	.75	75.3	1,740	480
Grader AA	1	.75	75.3	1,740	480
Grader AA	1	1.00	77.0	1,740	480
Grader A	2	.75	75.3	1,740	480
Breaking flume	1	.75	75.3	1,740	480
Breaking flume	1	.50	75.9	1,740	480
Ice conveyor	2	3.00	85.5	174	48
Ice conveyor	2	1.50	82.0	174	48
Icemaker	1	33.00	90.0	1,740	480
Storage freezer	2	20.00	86.5	8,760	8,760
Blast freezer	3	20.00	86.5	4,176	1,152

Appendix Table 8. Estimated annual electricity costs, by equipment item, two operating scenarios, synthesized shrimp processing plant, Mississippi Gulf Coast, 1986.

Item	Scenario I		Scenario II	
	($)	(% of total)	($)	(% of total)
Baffle system	193	.47	54	.20
Grader AA	223	.55	62	.22
Grader A	193	.47	54	.20
Breaking flume	161	.40	28	.10
Ice conveyor	31	.08	9	.10
Icemaker	1,053	2.60	285	1.00
Storage freezer	22,665	55.60	22,665	81.20
Blast freezer	16,207	40.00	4,471	16.20
Flourescent light	40	.10	25	.09
Total[1]				

[1] Totals do not add to 100 because of rounding.

Appendix Table 9. Manufacturer suggested daily water requirements for a synthesized shrimp processing plant operating at capacity, by item, Mississippi Gulf Coast, 1986.

Equipment Item	Daily Water Requirement
	(gallons)
Ice baffle receiving tank	1,500
AA-C5 shrimp grader	100
A-C5 shrimp grader	100
Ice baffle receiving tank	2,000
Deheading flume system with receiving tank	2,000
Icemaker	750
Total	6,450

Appendix Table 10. Results of time-motion studies concerning hand processing of freshwater shrimp, recorded in pounds per minute, and performed by a seven-man crew, Mississippi State University, 1986.

Item	Number Processed	Time Taken to Process	Weight of Processed Shrimp	Shrimp Processed/ Minute
	(no.)	(min)	(lb)	(lb/min)
Jumbo shrimp	26	2.33	3.9	1.6
Large shrimp	468	4.50	55.0	12.0
Medium shrimp	500	5.80	28.3	4.88
Small shrimp	350	5.54	7.5	1.35
Average, all sizes	336	4.54	23.7	5.22

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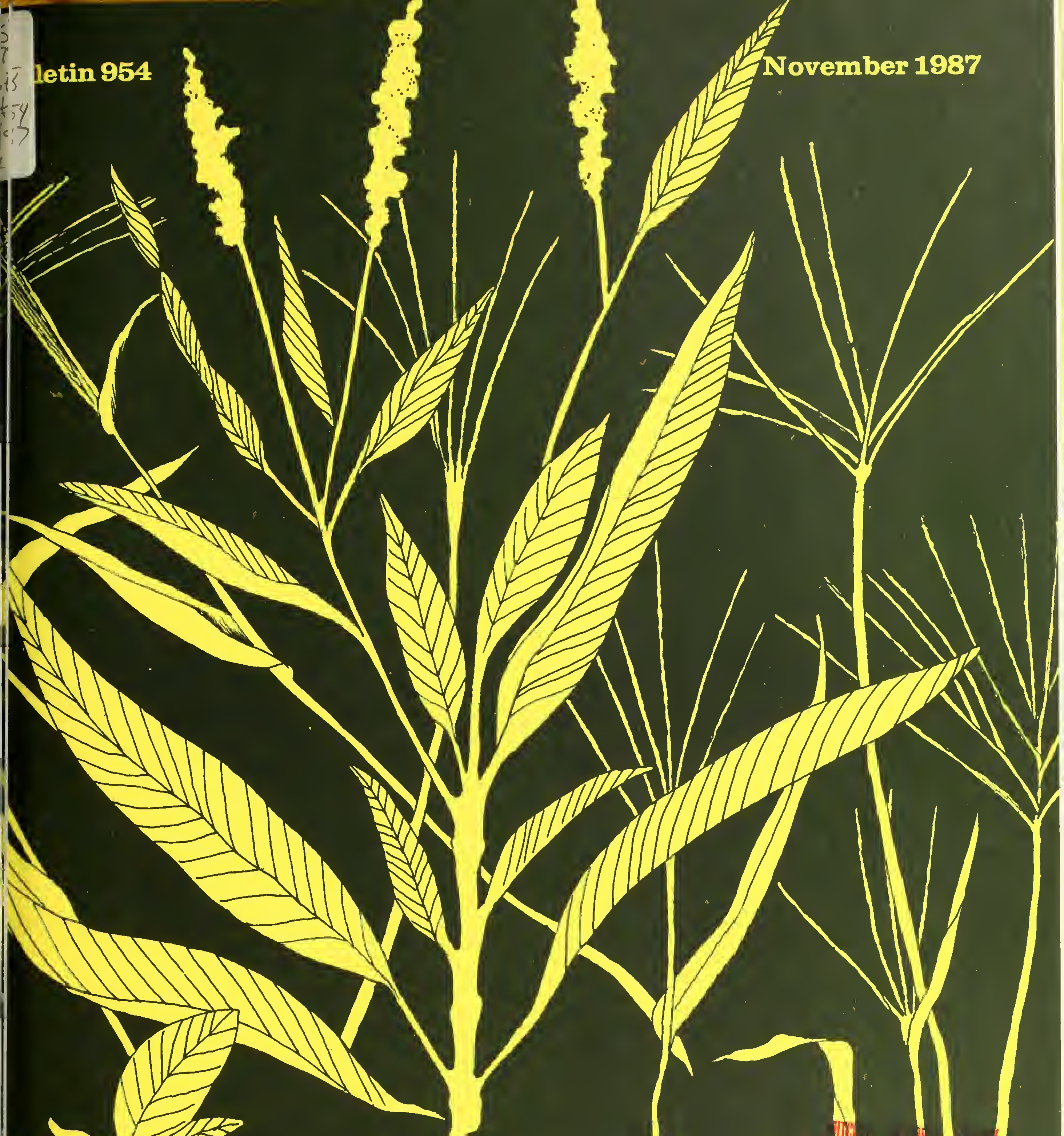

Weed Population Changes in No-till Soybeans

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Weed Population Changes in No-till Soybeans

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No-tillage has been suggested as a means of reducing soil losses from highly erodable soybean fields in Mississippi. Research at the MAFES North Mississippi Branch on a Grenada silt loam soil with a 5% slope showed that 8 tons of soil per year can be conserved by planting soybeans no-till (6).

The reluctance of many farmers to accept no-tillage soybean production has been partially due to its high frequency of weed control failures. Experiments conducted in soybean fields with heavy weed infestations have shown that not using preplant tillage increases the likelihood for poor weed control (1, 3). Farmers trying no-till soybeans for the first time are usually advised to choose fields with low weed infestations. Information on what types of weeds they should expect after several years of no-tillage in these fields is not available. Most no-tillage weed control experiments have been conducted in fields already heavily infested with weeds.

Eliminating tillage in corn has been shown to cause shifts in weed species. In Ohio research, no-till corn fields became infested with perennial weeds that are usually controlled with tillage. These included such weeds as Canada thistle, horsenettle, hemp dogbane, and common dandelion (7).

A 12-year experiment at the North Mississippi Branch at Holly Springs was begun in 1981 to determine whether weed control can be maintained in no-till soybeans in a field initially low in weed infestations. The effects of herbicides and cultivation on weed species are being studied. This preliminary report contains results through April 1987.

Materials and Methods

The experiment was established on a Grenada silt loam soil (fine silty, mixed, thermic Glossic Fragiudalf) with 1-5% slope. Analysis of soil samples collected from 0 to 6 inches deep in 1983 showed a pH of 6.2 and an organic matter level of 0.7%. The site, which had been used for soybean variety trials, had been kept weed-free for 5 years prior to beginning this study.

The experimental design was a split plot with herbicide treatment as main plots. Main plots were 26.7 feet (8 rows) wide and 30 feet in length. Each sub-plot contained four rows, which were either cultivated or not cultivated. All treatments were replicated four times. Individual plots were located on the same site each year.

Soybean varieties and planting dates were Forrest, June 10, 1981; Forrest, May 19, 1982; Essex, June 3, 1983; Forrest, June 1, 1984; Centennial, June 25, 1985; and Asgrow 5980, May 9, 1986. Fertilizer (300 pounds of 0-20-20 per acre) was drilled 2 inches to the side of the row at planting each year. Soybeans were planted with a John Deere 7000® planter equipped with ripple coulters from 1981 to 1985. A Cole® planter with fluted coulters was used in 1986. Soybeans were planted in 40-inch rows in 1981, 1982, 1983, and 1986. Rows were narrowed to 36 inches in 1984 and 1985.

A decision had to be made early in the study as to whether herbicide treatments would remain constant or be upgraded when superior herbicides became available. Not changing herbicides would have allowed more definitive statements on herbicide efficacy. However, at the end of 12 years, the results might have shown that it is not possible to maintain weed control in no-till soybeans when, in fact, farmers could do so by using new herbicides as they are released. Since evaluating herbicide efficacy was secondary to the broader objective of determining whether weed control can be maintained, herbicides were upgraded as warranted.

Table 1 lists the herbicides that were applied preplant to existing weed foilage (PPF), preplant incorporated (PPI), or preemergence (PRE) to main plots each year. Treatment No. 6 was a conventionally tilled control. Treatments 1-5 were all no-till planted. The conventionally tilled control plots were chiseled and disked before the PPI herbicides were applied. Incorporation was performed immediately afterwards with two passes by a finishing harrow in the row direction, followed by planting.

PPF herbicides (glyphosate, paraquat, glufosinate) were applied 10 days prior to planting in 1986 instead of tank mixing them

Table 1. Preplant and preemergence herbicide applications to no-till (Treatments 1-5) and conventionally tilled (Treatment 6) mailn plots in 1981-86.

Trt. No.	Herbicides (1981-84)	Rate/Acre	Applied[1]	Herbicides (1985)	Rate/Acre	Applied	Herbicides (1986)	Rate/Acre	Applied
		(lb a.i.)			(lb a.i.)			(lb a.i.)	
1	Roundup® 4L (glyphosate) + Sencor® 4L (metribuzin)	1.0 0.375	PPF-(AP)	Unchanged	Unchanged	Unchanged	Roundup 4E Sencor 4L	1.0 0.375	PPF-(BP) PPF-(AP)
2	Paraquat® CL 2E (paraquat) + X-77® Spreader + Surflan® 4AS (oryzalin)	0.25 0.5% 1.0	PPF-(AP)	Unchanged	Unchanged	Unchanged	Paraquat CL 2E + X-77 Canopy® 75 DG[3]	0.25 0.5% 0.375	PPF-(BP) PPF-(AP)
3	Paraquat CL 2E + X-77 Spreader + Dual® 8E (metolachlor)	0.25 0.5% 2.0	PPF-(AP)	Unchanged	Unchanged	Unchanged	Paraquat CL 2E + X-77 Turbo® 8E[4]	0.25 0.5% 2.0	PPF-(BP) PPF-(AP)
4	Paraquat CL 2E + X-77 Spreader + Lasso® 4E (alachlor)	0.25 0.5% 2.0	PPF-(AP)	Unchanged	Unchanged	Unchanged	Paraquat CL 2E + X-77 Lasso ME 4E	0.25 0.5% 2.0	PPF-(BP) PPF-(AP)
5	Paraquat CL 2E + X-77 Spreader + Lasso 4E	0.25 0.5% 3.0	PPF-(AP)	Ignite® 1.67E[2] + X-77 + Lasso 4E	0.75 0.5% 2.0	PPF-(AP)	Ignite 1.67E + X-77 Lasso ME 4E	0.75 0.5% 2.0	PPF-(BP) PPF-(AP)
6	Treflan® 4E (trifluralin) Sencor 4L	0.75 0.375	PPI PRE	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged

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[1] PPF = preplant to existing weed foliage (AP) = applied at planting, (BP) = applied 10 days before planting; PPI = preplant soil incorporated 2 inches with a finishing harrow; PRE = preemergence.

[2] Ignite 1.67E was tested as HOE 39866. Glufosinate is its common name.

[3] Canopy 75DG is 64.3% metribuzin and 10.7% chlorimuron.

[4] Turbo 8E is 6.55/1.45 ppg mixture of metolachlor/metribuzin.

Table 2. Postemergence herbicide applications to no-till (Treatments 1-5) and conventionally tilled (Treatment 6) main plots in 1981-86.

Trt. No.	Herbicides[1] (1981)	Rate/Acre	Applied[4]	Herbicides (1982-84)	Rate/Acre	Applied	Herbicides (1985)	Rate/Acre	Applied	Herbicides (1986)	Rate/Acre	Applied
		(lb a.i.)			(lb a.i.)			(lb a.i.)			(lb a.i.)	
1	Paraquat CL 2E + X-77 Spreader	0.125 0.5%	Dir.	Unchanged	Unchanged	Unchanged	Scepter® 1.5AS (imazaquin) + X-77	0.1875 0.5%	OT	Scepter 1.5AS + X-77	0.1875	OT
2	Lorox® 50W (linuron) + X-77 Spreader	0.75 0.5	Dir.	Unchnaged	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged	Butyrac® 175 (2,4-DB) Gemini® 60DG[6] + X-77 Spreader	0.2 0.75 0.5%	Dir. Dir.
3	Assure® 0.8E (quizalofop)[2]	0.15	OT	Verdict® 2E (haloxyfop)[5] + X-77 Spreader	0.125 0.125%	OT	Unchanged	Unchanged	Unchanged	None		
4	Poast® 1.53E (sethoxydim) + Atplus® 411F[3]	0.375 1.25%	OT	Poast 1.53E + Atplus 411F	0.2 1.25%	OT	Poast 1.53E + Agri-Dex® Crop Oil	0.2 1.25%	OT	Unchanged	Unchanged	Unchanged
5	Poast 1.53E PL Atplus 411F	0.375 0.125%	OT	Fusilade® 4E (fluazifop) + X-77 Spreader	0.20 0.125%	OT	Fusilade 2000 1E (fluazifop) + X-77 Spreader	0.1875 0.125%	OT	Unchanged	Unchanged	Unchanged
6	None	–	–	None	–	–	None	–	–	None	–	–

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[1] Basagran® 4E (bentazon) + Blazer® 2S (acifluorfen) was applied over-the-top 8-inch soybeans at 0.5 + 0.375 lb ai/A, respectively, on the entire area in 1981-1985. In 1986, the mixture was only applied to Treatments 3-6.

[2] Assure 0.8E was tested as NCI 96683 which was later changed to DPX-F 6202.

[3] Atplus 411F is a crop oil concentrate (83% oil, 17% surfactant).

[4] Dir. = directed spray (20-inch band) to 8-inch soybeans, OT = over-the-top of soybeans. Except for Scepter which was applied OT to 8-inch soybeans, all other OT herbicides were applied when johnsongrass reached 15 inches or when other grasses reached 2 inches whichever came first.

[5] Verdict 2E was tested as XRM 4570.

[6] Gemini 60 DG is a 12:1 mixture of linuron and chlorimuron.

with the PRE herbicides as was done in 1981-85. The post-emergence herbicides used are listed in Table 2.

All herbicides were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 20 gallons of solution per acre on a broadcast basis. Post-directed herbicides were applied in a 20-inch band centered on each row with two off-center flat fan nozzles per row when soybeans were 8 inches tall.

Cultivation was performed on designated sub-plots 3 to 5 weeks after planting. A cultivator with three plows per row middle was used in 1981-84. A Glencoe® cultivator with three coulters followed by a sweep plow was used in 1985 and 1986.

Weeds in plots were identified and measured March 15, 1984 and April 30, 1987. Their distributions in the field were visually described as very abundant (VA), abundant (A), moderate (M), scattered (S), or very scattered (VS).

Plots were visually rated for percent weed control (0 = no control, 100 = complete control) on Sept. 8, 1982 and July 22, 1985. An evaluation of the infestation of perennial grasses was made at soybean maturity Oct. 24, 1983 and Oct. 2, 1986.

A scale map of each plot was constructed and perennial grass boundaries were recorded on the map by field inspection. The infested areas on the map were darkened and the percentage of these areas relative to the total plot area was determined with an image analyzer. Mapping was not suitable for perennial broadleaf weeds because they did not form distinct boundaries. Annual grass and and all broadleaf weed populations were visually estimated as either present in numbers sufficient to affect yields, present in low numbers, or absent. These were subjective ratings, based on the opinions of the authors making the observations. It should be borne in mind that several weed species with low numbers may have had a cumulative affect on soybean competition. All weed notations were made from the center two rows of each sub-plot. Botanical nomenclature for common weed names used hereafter in this text is shown in the Appendix.

Soybeans were harvested from the center two rows with a plot combine. Yields were converted to bushels per acre.

Results

When field observations were made on March 15, 1984, 17 early season weed species were identified in the experimental area (Table 3). A slightly larger variety of weeds was found on April 30, 1987 (Table 4). However, the 1987 observation was made later in the spring and several warm season weeds such as johnsongrass had emerged. No consistent relationship between treatments and the types of weeds in plots was found in either year. Little barley was a dominant cool season weed in all plots each spring (Figure 1).

In 1987, weeds other than little barley were not as abundant in three replications of the conventionally tilled main plots (Treatment 6) as in the no-till plots. However, one replication of the conventionally tilled treatment was indistinguishable from no-till plots in either abundance or diversity of early season weeds. No explanation other than field variability is available.

Narrowleaf vetch, pokeweed, and Carolina horsenettle increased in abundance from 1984 to 1987. Horseweed (Figure 2) declined from being rated as very abundant in March 1984 to very scattered in April 1987. One possible explanation for this may be more competition from winter weeds. Several early maturing cool season weeds, such as henbit, were observed to be more abundant earlier in the spring than the April 30, 1987 rating date indicated.

Weed infestation levels were low in all plots in 1981-83 and soybean yields did not differ significantly

Table 3. Size, distribution, and growth stages of early season weeds in plots on March 15, 1984.

Weed Name	Distribution[1]	Growth Stage	Size Ht. or Dia.[2] (in.)
Little barley	VA	Vegetative	1-4 ht.
Annual bluegrass	VA	Seedling	1-2 ht.
Mousetail	VA	Flowering	1 ht.
Horseweed	VA	Vegetative	1 ht.
Carolina geranium	VA	Vegetative	6 dia.
Bittercress	VA	Flowering	> 4 ht.
Henbit	A	Flowering	> 4 ht.
Virginia pepperweed	A	Vegetative	2-4 dia.
Shepherdspurse	M	Flowering	6 ht.
Mouseear chickweed	M	Vegetative	1 ht.
Wild garlic	M	Vegetative	6 ht.
Buttercup	M	Vegetative	4 dia.
Cutleaf eveningprimrose	S	Vegetative	2-6 dia.
Hop clover	S	Vegetative	1 ht.
Narrowleaf vetch	S	Vegetative	1-2 ht.
Common chickweed	VS	Vegetative	1 ht.
Whitlowort	VS	Vegetative	1 ht.

[1] Infestation was uniform over the entire area. Distributions were described as very abundant (VA), abundant (A), moderate (M), scattered (S), or very scattered (VS).

[2] Ht. = Height; Dia. = Diameter

Table 4. Size, distribution, and growth stages of weeds before burndown on April 30, 1987.

Weed Name	Distribution[1]	Growth Stage	Heigth (in.)
Narrowleaf vetch	M-VA	Flowering	10-23
Little barley	VA	Seedheads present	10-14
Carolina geranium	M	Flowering	9-12
Mouseear chickweed	M	Flowering	8-10
Hop clover	M	Flowering	5-10
Johnsongrass	S-A	Vegetative	10-15
Carolina horsenettle	S-M	Vegetative	3-10
Bermudagrass	S-M	Vegetative	1-2
Common chickweed	S	Flowering	15
Virginia pepperweed	S	Seed present	12
Buttercup	S	Seed present	5-8
Pokeberry	S	Vegetative	5-25
Wild lettuce	S	Vegetative	8-12
Curly dock	S	Seed present	25-30
Wild garlic	S	Vegetative	15
Chervil	S	Flowering	12-18
Horseweed	VS	Vegetative	8-10
Bracted plantain	VS	Seed present	10
Red sorrell	VS	Flowering	8-10
Wild oats	VS	Seed present	20

[1] Infestation was not uniform over the area, but there was not a consistent pattern of infestations relative to main or sub-plot treatments. Distributions were described as very abundant (VA), abundant (A), moderate (M), scattered (S), or very scattered (VS).

Table 5. Effects of herbicides and cultivation on soybean yields in 1981-86.

Number	Cultivated	1981	1982	Soybean yields[1] 1983	1984[2]	1985	1986
		(bu/A)					
1	Yes	28.4	32.1	13.9	24.2	29.9	21.4
	No	29.7	36.8	12.6	17.9	26.6	19.3
2	Yes	33.0	38.4	14.7	19.4	22.5	25.4
	No	31.4	36.8	13.0	8.9	20.2	26.1
3	Yes	35.3	35.7	14.7	18.5	31.6	25.0
	No	30.9	35.1	11.1	11.8	25.5	16.5
4	Yes	35.4	38.2	15.9	18.3	34.5	32.2
	No	36.7	37.9	12.1	10.1	29.6	25.1
5	Yes	37.3	32.1	17.3	14.5	37.3	30.1
	No	34.9	36.5	14.5	14.9	30.8	26.6
6	Yes	33.0	35.5	13.5	26.5	46.8	30.5
	No	33.7	38.5	12.1	24.8	39.5	27.0
LSD 0.05[3]		NS	NS	NS	4.0	8.7	4.3
LSD 0.05[4]		NS	NS	NS	2.0	3.4	2.3
CV (%)		20.8	13.9	20.7	21.5	22.0	15.6

[1] Average of four replications.

[2] Damage to some plots during cultivations affected 1984 yield results.

[3] LSD 0.05 values for comparing two herbicide means. Statistical analysis of 1984 yields showed a cultivation x herbicide interaction. NS = not significant.

[4] LSD 0.05 values for comparing cultivated and not cultivated means.

with main or sub-plot treatments (Table 5). Weed control was recorded as nearly perfect for all treatments in field notes made in 1981. Visual ratings for weed control on Sept. 8, 1982 showed that grasses were absent from all plots and broadleaf weed control averaged greater than 85 percent for all treatments. Although 26 weed species were observed and recorded from the experimental area on Oct. 24, 1983, no single species was judged abundant enough to lower soybean yield (Table 6). Bermudagrass, broomsedge, and johnsongrass had begun to invade some plots, but were only present in small areas.

Soybean rows were narrowed from 40 to 36 inches in 1984 and 1985 because of research showing yield increases from narrower rows (2). However, unusually high weed infestation levels developed in the 52-inch row middle between plots during 1984 and 1985. To alleviate this problem, rows were returned to 40-inch widths in 1986.

Soybean yield differences in main plots and sub-plots were first observed in 1984 (Table 5). As mentioned, soybean rows were narrowed to 36 inches in 1984. By error, a cultivator adjusted for 40-inch rows was used that year, resulting in damage to some rows. Statistical analysis of 1984 soybean yields showed an interaction between main plots and sub-plots. Considering the problems with the cultivation and that no interaction was found in 1985 or 1986, the 1984 yield results are viewed with some skepticism.

Horseweed was a dominant weed in no-till plots, which were burned down with paraquat in 1984. It was less abundant in plots receiving Roundup® or preplant tillage, which probably contributed to the numerically lower yields in other no-till plots in 1984. Tennessee researchers observed greater horseweed control from Roundup than from paraquat

(5). The systemic activity of Roundup as contrasted to the contact activity of paraquat was cited as the reason for the difference. In the Tennessee study, excellent horseweed control was achieved when 2,4-D was applied 9 days before planting, followed by paraquat and residual herbicides.

Soybean yields varied widely between main plots in 1985. The lowest yielding treatment was Treatment 2, which had Surflan® applied preemergence (Table 5). The directed spray of Lorox to 8-inch soybeans in Treatment 2 was not highly effective on weeds such as horsenettle that were not previously controlled by paraquat. By the time soybeans reached a height of 8 inches, these weeds were also 8 inches tall or taller. Yields from conventionally tilled plots (Treatment 6) were high relative to other treatments. This cannot be explained completely by weed control because the no-till Treatment 5 had higher weed control ratings but yielded less (ratings not shown).

The weedy vegetation, primarily little barley and narrowleaf vetch, was so dense at planting in 1985, that identifying the tops of seedbeds from 1984 was nearly impossible. This resulted in poor seed placement with the planter because the planter depth control wheels sometimes rode the shoulders of the beds. Plot areas with poor stands were hand planted with a hoe shortly after planter-planted soybeans emerged. Killing the weeds 10 days prior to planting in 1986 provided much better planting conditions.

Erect spurge was rated as being present in high enough numbers to reduce soybean yields in many plots in 1986 (Table 7). Canopy®, which was substituted for Surflan in Treatment 2, resulted in the best spurge control of the herbicide treatments evaluated. Carolina horsenettle was rated as abundant enough to affect soybean yields in Treatments 2-5. Preplant tillage probably controlled most horsenettle plants in Treatment 6. Roundup (Treatment 1) gave better PPF horsenettle control than paraquat or Ignite® (Figure 3).

Pokeweed may pose a special problem for no-till farmers. As Table 7 shows, pokeweed plants did not occur in high numbers in any plots in 1986, but they caused considerable soybean staining when the purple berries went through the combine (Figure 4). Grain elevators would probably dock soybeans with such stain. Pokeweed plants measuring 25 inches tall were observed April 29, 1987 (Figure 5). The burndown herbicides used in this study did not control large pokeweed plants. In many plots, regrowth was

Figure 1. Little barley, a naturally occurring cool season grass, was easily killed with PPF herbicides.

Figure 2. Competition from cool season weeds may have contributed to the decline of horseweed in non-till plots in 1985 and 1986. Horseweed germinates in the fall and lives through the winter in the rosette stage.

observed within a week of burndown applications (Figure 6). The only herbicide main plots in which it was completely absent were Treatment 2. As this study is continued, attention will focus on this weed to see whether by coincidence pokeweed has not yet invaded these plots or if one of the herbicides in Treatment 2 is effectively controlling it.

Generally, treatments which included over-the-top grass herbicides provided good grass control, as evidenced by ratings and plot area infestation percentages shown in Table 7. Treatment 1 main plots produced a low yield in 1986, despite better horsenettle control from Roundup. This was because southern crabgrass was not controlled.

After the third year of the study, no-till and conventionally tilled plots showed significant annual yield increases from cultivation (Table 5). Only three weed species were observed in cultivated conventionally tilled plots in 1986 as compared to 10 species in noncultivated conventionally tilled plots (Table 7). This indicates that even with conventional tillage, cultivation was required to maintain the original low infestation status of the field. Plant residue accumulations on the soil surface of no-till plots caused frequent clogging of cultivator sweeps in 1984. This necessitated the use of a cultivator with coulters in 1985 and 1986. Cultivation usually did not rid plots of such weeds as pale smartweed, but it usually reduced their numbers (Table 7). In a few cases, cultivation resulted in higher perennial grass infestation percentages than no cultivation. Cultivator sweeps possibly carried bermudagrass and johnsongrass rootstocks to other parts of plots where they started new plants. Cultivation may have enhanced soybean yields by providing more favorable soil conditions for soybean growth. A review article on cultivation research in *Crops and Soils* magazine cited several studies in which soybean yields were increased with early season

Table 6. Weed population ratings for broadleaf weeds, sedge, and annual grasses and the percentage of plot areas infested with perennial grasses for no-till (Treatments 1-5) and conventionally tilled (Treatment 6) soybeans on Oct. 24, 1983.

		Weed population ratings[2]																							Percentage of plot areas infested with perennial grass[2]		
Treatment number	Cultivated	Spiny amaranth	Carpetweed	Cocklebur	Virginia copperleaf	Curly dock	Carolina horsenettle	Horseweed	Honeyvine milkweed	Entireleaf morningglory	Pitted morningglory	Redroot pigweed	Poison ivy	Pokeweed	Prickly sida	Common ragweed	Red sorrel	Erect spurge	Nutsedge	Goosegrass	Southern crabgrass	Foxtail	Fall panicum	Broadleaf signalgrass	Bermudagrass	Broomsedge	Johnsongrass
1	Yes	+	−	+	−	−	+	−	−	−	−	+	−	−	+	−	−	+	−	−	+	−	−	+	6	0	6
	No	−	−	−	−	−	+	−	−	−	+	+	−	−	+	−	−	+	−	+	+	−	−	+	1	2	1
2	Yes	−	−	+	−	+	+	+	−	−	+	+	−	−	+	−	−	+	−	+	+	+	−	−	9	1	2
	No	+	−	+	−	−	+	+	+	−	+	+	−	−	−	+	−	+	−	+	+	+	−	+	0	5	0
3	Yes	+	−	+	−	−	+	+	−	−	−	+	−	−	+	−	+	+	−	−	+	+	−	+	0	1	0
	No	+	−	+	−	−	+	+	−	+	+	+	−	+	+	−	+	+	+	−	+	+	−	+	0	1	1
4	Yes	+	−	+	−	−	+	−	+	−	+	+	−	−	+	−	−	+	−	+	+	+	−	+	1	1	0
	No	+	+	+	−	+	+	−	−	+	−	+	+	+	+	−	+	+	−	+	+	−	−	+	1	1	7
5	Yes	+	−	+	−	−	+	+	−	+	−	+	−	−	+	−	−	+	−	−	+	+	−	−	0	1	2
	No	−	−	+	−	−	+	+	−	+	+	+	−	+	+	−	−	+	−	+	+	−	+	+	0	1	0
6	Yes	−	−	−	−	−	+	−	−	+	−	+	−	−	+	−	−	+	−	−	−	−	−	−	1	1	0
	No	−	+	+	−	−	+	−	−	+	−	+	−	−	+	−	−	+	−	−	−	−	+	−	0	0	0

[1] Weed population ratings are summarized as follows: (–) species absent from plots in all replications; (+) species present in low numbers in at least one replication; and (x) species present in high enough numbers in at least one replication to affect soybean yields. No single weed was judged to be abundant enough to affect soybean yields on this date.

[2] Differences between percentages of plot areas infested with perennial grasses were not significant at the 5% level for herbicides or cultivation.

Figure 3. Paraquat applied PPF killed all existing weeds except horsenettle.

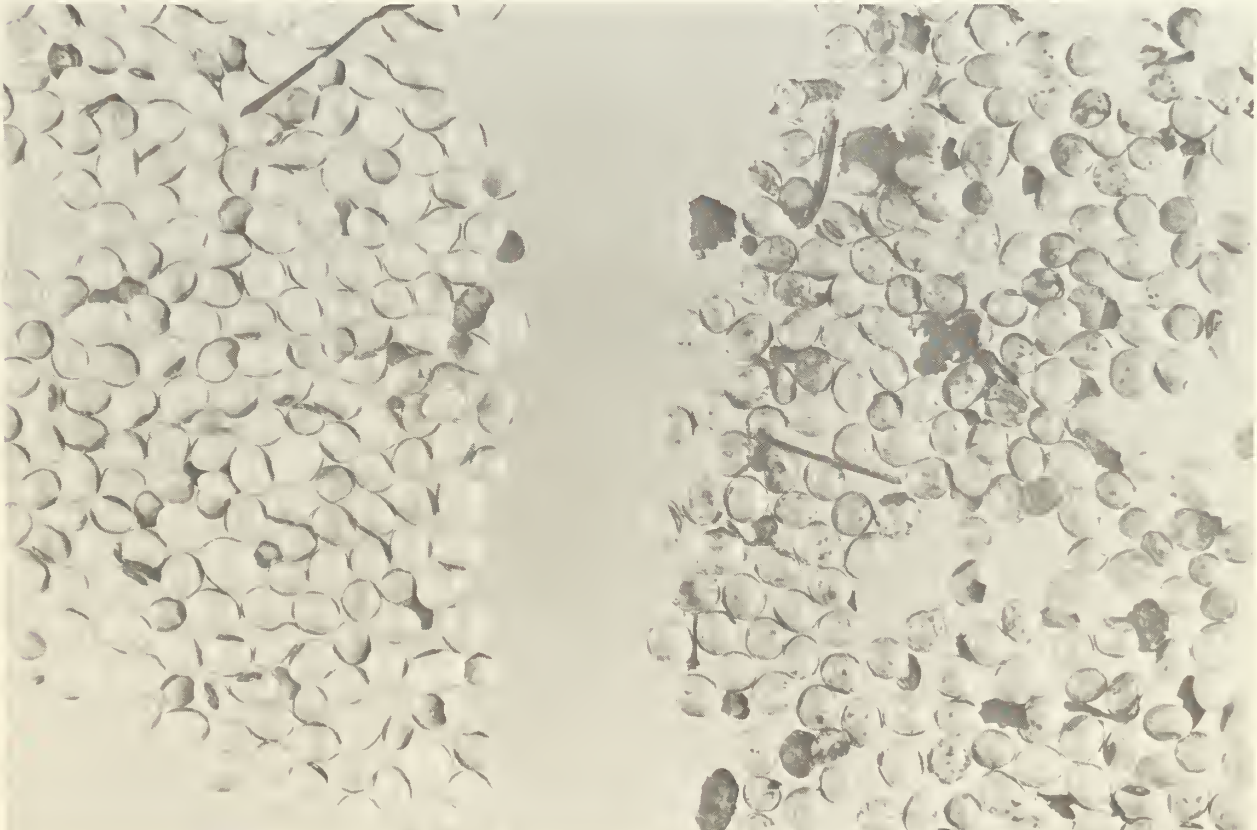

Figure 4. Soybean quality from harvested plots with pokeweed (right) was lower than plots without the weed (left). Soybeans on the right were stained by pokeweed.

cultivation even though there were not enough weeds to justify cultivation (4). Increased water infiltration rates due to breaking up soil surface crusts and creating small water storage areas was believed to be the reason for the increased yields in most cases. In an Illinois study on fields with 3 to 5 percent slope, soil loss was reduced with cultivation.

Conclusion

No-till soybeans were grown with low weed competition for 3 years (1981-83). No significant yield differences in main plots with different herbicides and sub-plots cultivated and non-cultivated were obtained during that period. Weeds, though they were mostly absent when the study began, gradually invaded and increased in number in some no-till plots each year.

PPF herbicides played an important role in the control of certain weeds. Roundup controlled horseweed better than paraquat resulting in lower yield with treatments using the latter herbicide in 1984. Control of Carolina horsenettle in 1986 followed a similar pattern.

Applications of over-the-top grass herbicides were required in main plots for good control of grasses in 1986.

Pokeweed plants were not considered abundant enough to affect soybean yields in 1986. However, the staining on soybeans during combining would likely cause dockage.

Cultivation was no substitute for good herbicide treatments, but it usually lowered the infestation level of weeds. Significant yield increases from cultivation were shown in 1984-86.

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Table 7. Weed population ratings for broadleaf weeds and annual grasses and the percentage of plot areas infested with perennial grasses for no-till (Treatments 1-5) and conventionally tilled (Treatment 6) soybeans on Oct. 2, 1986.

		Weed Population Ratings [2]															Percentage of plot areas infested with perennial grass[2]			
Treatment number	Cultivated	Cocklebur	Virginia copperleaf	Groundcherry	Carolina horsenettle	Horseweed	Entireleaf morningglory	Pokeweed	Prickly side	Pale smartweed	Erect spurge	Barnyardgrass	Southern crabgrass	Foxtail	Fall panicum	Broadleaf signalgrass	Bermudagrass	Broomsedge	Johnsongrass	Purpletop
1	Yes	+	–	+	+	–	–	+	+	+	x	+	x	+	–	+	4	0	7	1
	No	–	–	–	+	–	+	–	+	+	x	–	x	+	–	–	0	0	7	1
2	Yes	x	–	–	x	–	+	–	+	+	+	–	x	+	–	x	2	1	14	0
	No	–	–	–	+	+	–	–	–	+	–	–	x	+	–	+	0	3	1	0
3	Yes	+	–	+	+	+	–	+	–	+	x	–	+	+	–	+	0	0	3	0
	No	–	–	–	x	–	+	+	–	x	x	–	x	+	–	–	0	0	13	0
4	Yes	+	–	–	x	+	–	+	–	+	x	–	–	–	–	–	0	0	2	0
	No	+	+	–	x	–	–	+	–	x	x	–	–	–	–	–	0	2	7	0
5	Yes	+	–	–	+	–	+	+	–	+	x	–	–	–	–	–	1	0	0	0
	No	+	–	–	x	–	–	+	–	x	x	–	–	–	–	–	0	0	0	0
6	Yes	–	–	–	+	–	–	–	–	–	+	–	+	–	–	–	0	0	1	0
	No	–	–	+	+	+	+	+	–	+	x	–	+	–	+	x	2	0	2	0

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[1] Weed populations are summarized as follows: (–)species absent from plots in all replications; (+) species present in low numbers in at least one replication; and (x) species present in high numbers in at least one replication.

[2] Differences between percentages of plot areas infested with perennial grasses were not significant at the 5% level for herbicides or cultivation.

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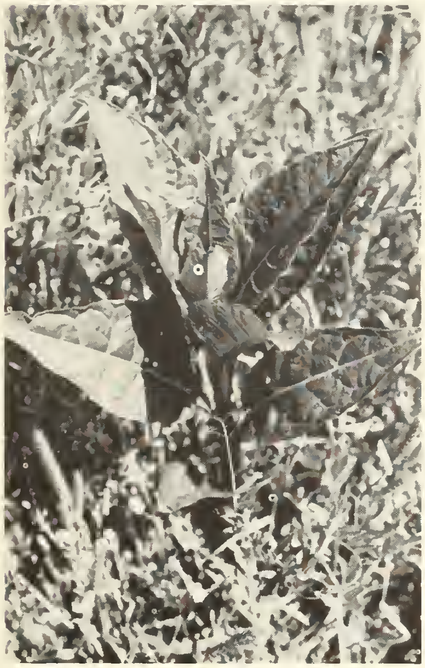

Figure 5. Pokeweed is a perennial weed which can grow quickly after emerging in early spring.

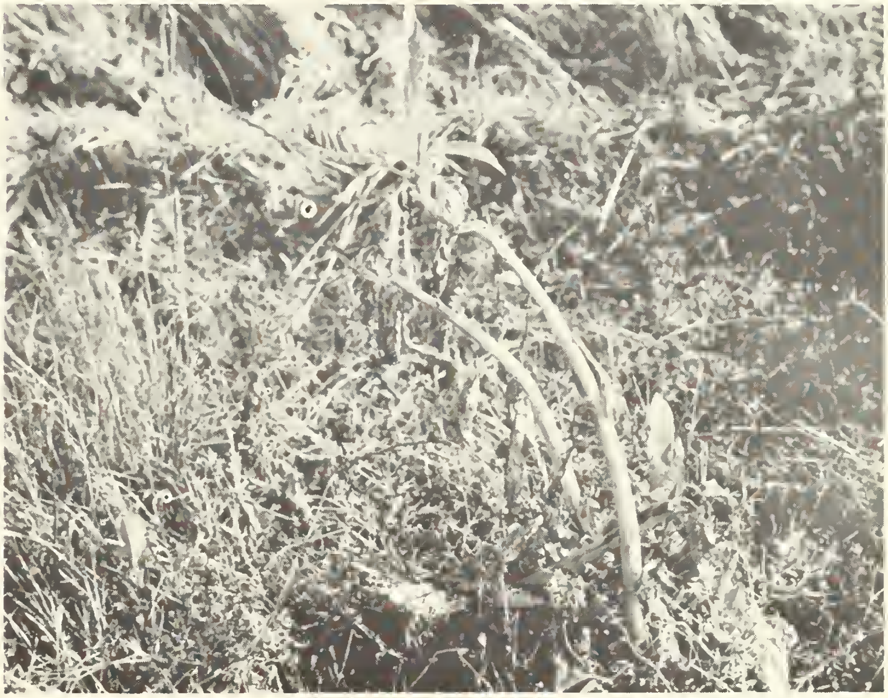

Figure 6. Regrowth was visible on this pokeweed in less than a week after receiving paraquat (PPF).

Appendix

Botanical nomenclature for common weed names used in the text.

Common name	**Botanical name**
Amaranth, spiny	*Amarantus spinosus*
Barley, little	*Hordeum pusillum*
Bermudagrass	*Cynodon dactylon*
Bittercress	*Cardamine hirsuta*
Bluegrass, annual	*Poa annua*
Broomsedge	*Andropogan virginicus*
Buttercup	*Ranunculus abortivus*
Carpetweed	*Mollugo verticillata*
Chervil	*Chaerophyllum tainturieri*
Chickweed, common	*Stellaria media*
Chickweed, mouseear	*Cerostium vulgatum*
Clover, hop	*Trifolium procumbens*
Cocklebur	*Xanthium penslyvanicum*
Copperleaf, Virginia	*Acalyha virginica*
Crabgrass, southern	*Digitaria sanguinalis*
Dock, curly	*Rumex crispus*
Eveningprimrose, cutleaf	*Oenothera laciniata*
Foxtail, yellow	*Setaria glauca*
Garlic, wild	*Allium vineale*
Geranium, Carolina	*Geranium carolinianum*
Goosegrass	*Eleusine indica*
Groundcherry	*Physalis heterophylla*
Henbit	*Lamium amplexicaule*
Horsenettle, Carolina	*Solanum carolinense*
Horseweed	*Erigeron canadensis*
Johnsongrass	*Sorghum halepense*
Lettuce, wild	*Lactuca scariola*
Milkweed, honeyvine	*Ampelamus albidus*
Mousetail	*Myosurus minimus*
Morningglory, entireleaf	*Ipomaea hederacea var. Integriuscula*
Morningglory, pitted	*Ipomoea lacunosa*
Nutsedge, purple	*Cyperus rotundus*
Panicum, fall	*Panicum dichotomiflorum*
Pepperweed, Virginia	*Lepidium virginicum*
Plantain, bracted	*Plantago aristata*
Poison ivy	*Rhus radicans*
Pokeweed	*Phytolacca americana*
Ragweed, common	*Ambrosia artemisiifolia*
Shepherdspurse	*Capsella bursa-pastoris*
Sida, prickly	*Sida spinosa*
Signalgrass, broadleaf	*Brachiaria platyphylla*
Smartweed, pale	*Polygonum lapathisolium*
Sorrel, red	*Rumex acetosella*
Spurge, erect	*Euphorbia maculata*
Vetch, narrowleaf	*Vicia angustifolia*
Whitlowort	*Draba verna*

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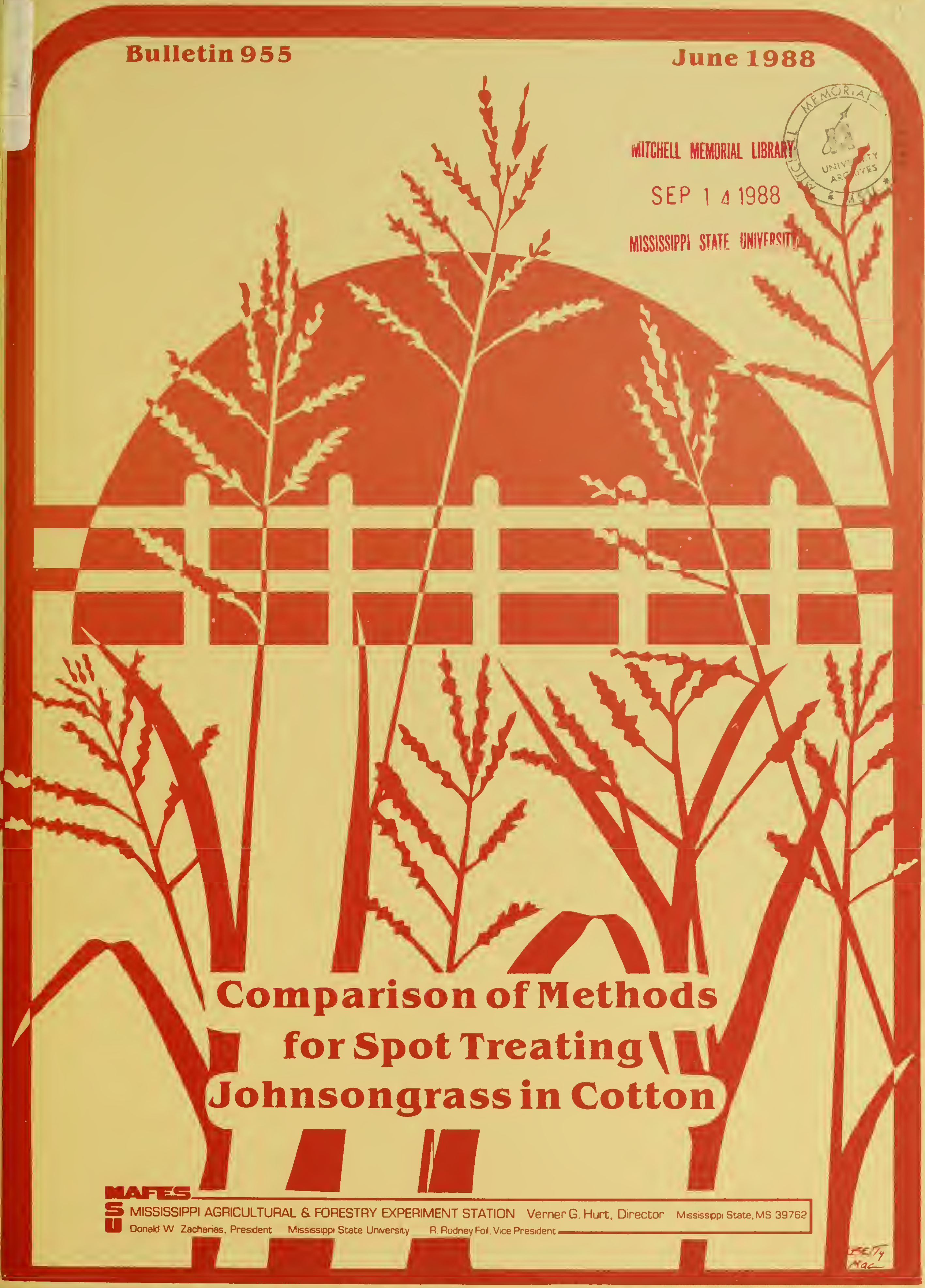

Comparison of Methods for Spot Treating Johnsongrass in Cotton

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Comparison of Methods for Spot Treating Johnsongrass in Cotton

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Comparison of Methods for Spot Treating Johnsongrass in Cotton

Introduction

Treatments with selective over-the-top herbicides have improved rhizome johnsongrass control in cotton. Cotton production techniques stress "clean" culture, and johnsongrass is usually confined to small areas or isolated plants in Mississippi cotton fields.

The application of over-the-top grass herbicides as spot treatments in cotton is currently a major method of johnsongrass control. Production costs are often reduced by spot spraying over those of broadcast application because less herbicide is usually required. The objective of the experiment reported in this bulletin was to measure the effectiveness of over-the-top grass herbicides for control of johnsongrass using several spot treatment methods, with and without prior use of preplant incorporated trifluralin ((Treflan 4E®).

Materials and Methods

A study was conducted on a silt loam soil (37% sand, 53% silt, 10% clay, 0.9% organic matter, pH 5.6) at the Delta Branch of the Mississippi Agricultural and Forestry Experiment Station, Stoneville, during 1985-1987. Cotton (DES '422' or DES '119') was planted in late April each year on an area which contained a natural infestation of johnsongrass. Treflan was applied at 1.0 lb ai/A (pound of active ingredient per acre) in 1985 or 0.75 lb ai/A in 1986 and 1987 to half the total number of plots, soil incorporated 3 to 4 inches deep by disking twice, operating a field cultivator, and hipping rows in March each year. The beds were re-hipped and then reduced to a final planting height of 3 inches with a row conditioner just prior to planting. Conventional production practices were used as recommended by the Mississippi Cooperative Extension Service.

The entire experimental site received fluometuron (Cotoran 4L®) applied preemergence at 1.25 lb ai/A each year, plus directed postemergence herbicides applied to a 14-inch band. Broadcast rates and application dates of directed sprays were Cotoran 4L + MSMA at 1 + 1.6 lb ai/A on May 21, 1985, Bladex 4L® + surfactant at 0.6 lb ai/A + 0.25% on June 17, 1985; Cotton-Pro 4L® + surfactant at 0.5 lb ai/A + 0.25% on May 16, 1986, Cotoran 4L + MSMA 0.8 + 1.5 lb ai/A on June 4, 1986, Bladex 4L + MSMA at 0.6 + 2 lb ai/A on June 19, 1986; Caparol 4L® + surfactant at 0.5 lb ai/A + 0.5% on May 20, 1987, and Cobra 2E® + Agri-Dex® crop oil concentrate at 0.25 lb ai/A + 0.25% on June 1, 1987. Row middles were cultivated and broadleaf weeds were removed by selective hand hoeing.

Johnsongrass control treatments were arranged factorially (preplant and no preplant Treflan, spot treatments) using a randomized complete block design with three replications. Each plot was four 40-inch rows and 40 feet long. Spot treatments and Treflan were applied to the same plots each year. The herbicides used for spot treatments were SC 1084 (an experimental discontinued after 1985) in 1985 and clethodim (Select 2E®) in 1986 and 1987. Agri-Dex crop oil concentrate was added to all in-season treatments at 1.25% v/v.

Individual spot treatments were made with a 2-gallon hand-held "Spray-Doc® " sprayer (concentrations of 0.12 and 0.24 % v/v), a hand-held "Spot Gun® " (Figure 1) applicator (concentrations of 0.06, 0.12, and 0.24 % v/v), and an electrically weed-activated tractor-mounted spot applicator

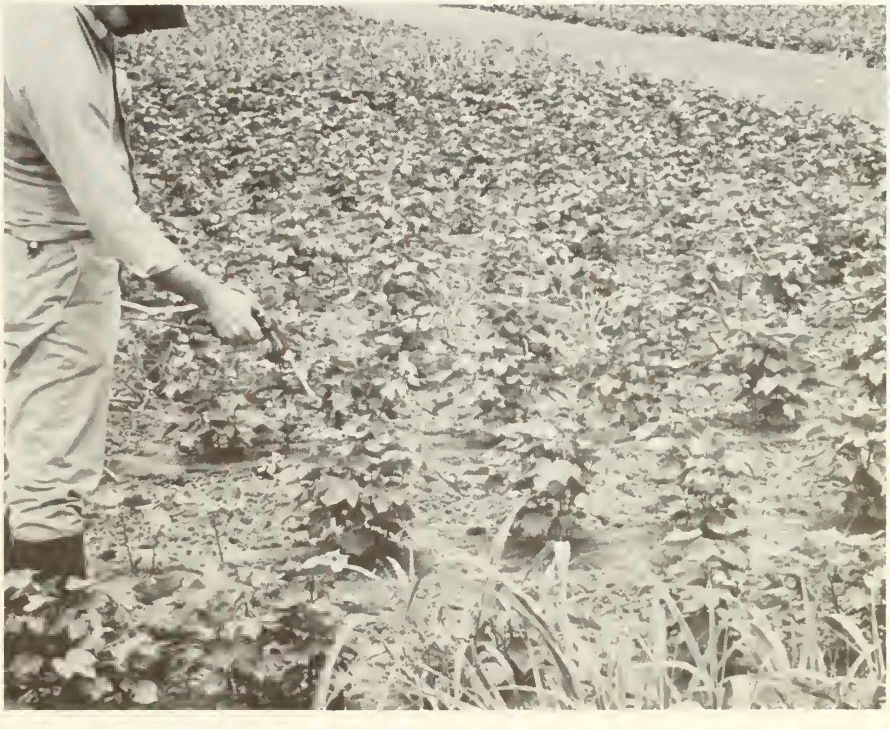


Figure 1. Hand spot treatments were made with the "Spot Gun" sprayer shown here or with a 2-gallon "Spray Doc" sprayer.

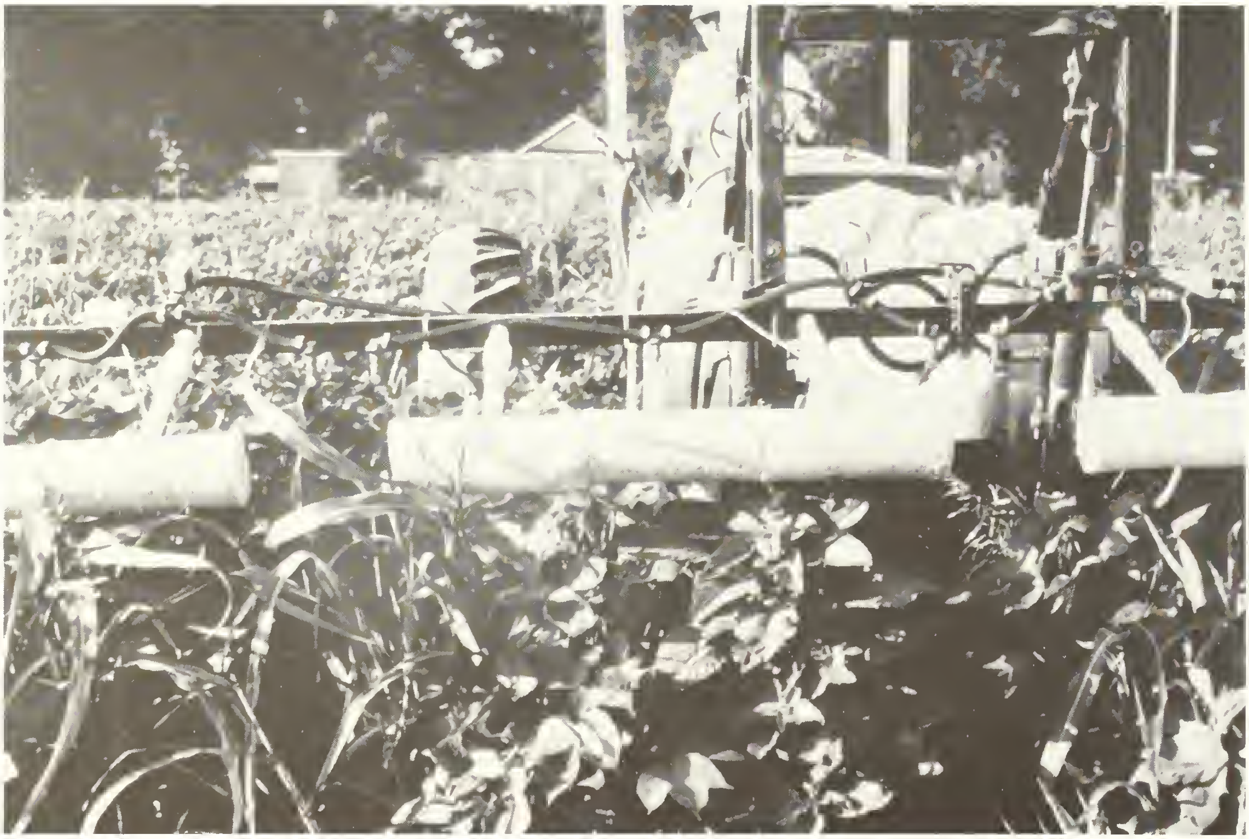
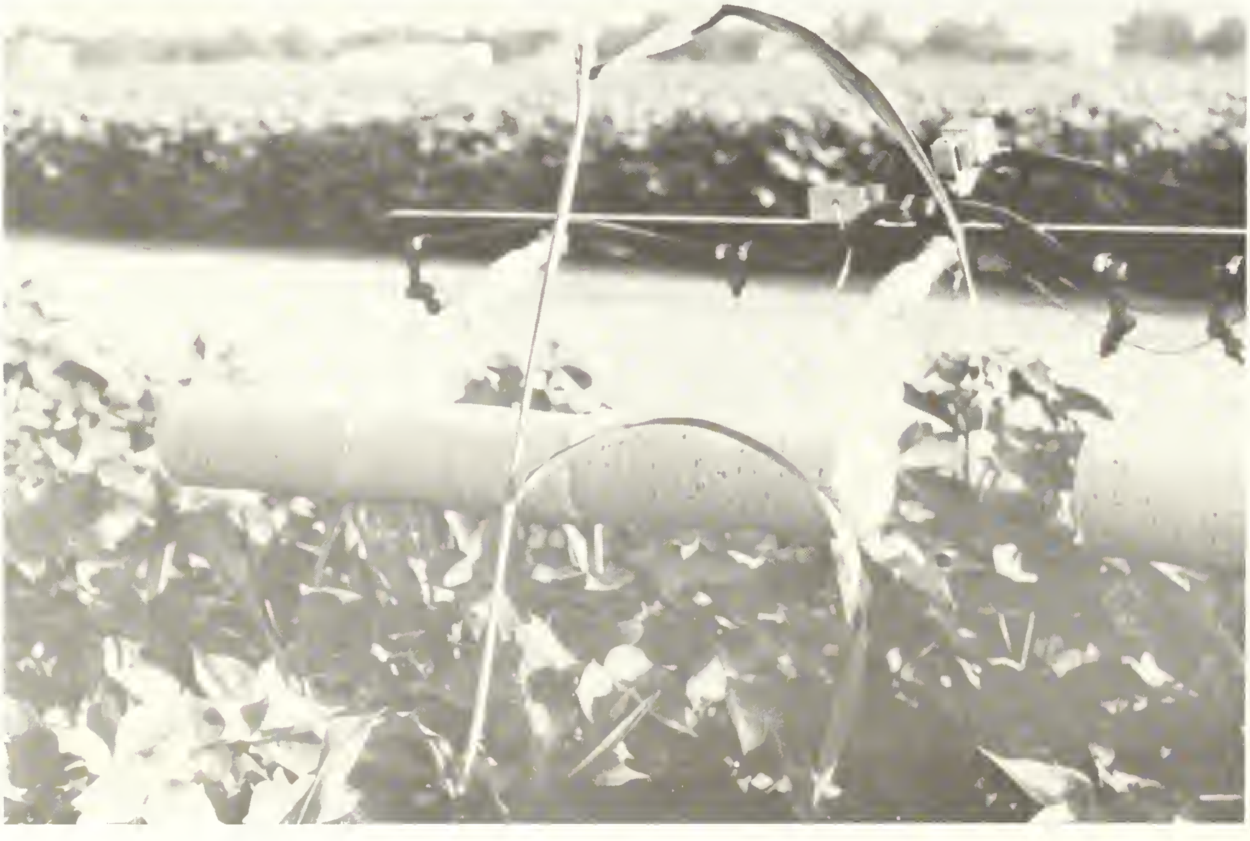


Figure 2. Spot treatments were applied with a tractor-mounted applicator (above) that was electrically activated when sensor contacted a johnsongrass plant (below). Note the three-nozzle spray arrangement.



(Figure 2) applying 0.0625 and 0.125 lb ai/A calibrated to deliver 10 gal/A broadcast volume when activated.

A control treatment of 0.125 lb ai/A of SC 1084 or Select was applied with a conventional boom sprayer using one nozzle per row calibrated to deliver a broadcast volume of 10 gal/A. Treatments applied by hand were made once each season, usually in mid-June. With each pass, two crop rows were sprayed to "cover" johnsongrass foliage. The "Spot Gun" device was calibrated to deliver a measured volume of 5, 10, or 20 ml/squeeze in a straight stream, which was directed toward the main culm(s) of the johnsongrass plants that were at or above the height of cotton plants.

The tractor-mounted spot sprayer consisted of a conventional spray system with three cone tip nozzles per row arranged with one nozzle centered over the row and one on each side directed at a 45-degree angle to the row (Figure 2). A solenoid valve was added to each row to activate the spray nozzles and a sensor that activated the solenoid valve was located about 20 inches ahead of the nozzles. When vegetation (e.g. johnsongrass) contacted the sensor, it activated the spray system for a predetermined time interval. The sensors, solenoids, and spray nozzles were mounted on a frame attached to the front of the tractor. The height of the system was controlled by the tractor's hydraulic system to operate about 4 inches above the cotton plants.

Tractor-mounted spot treatments were applied three times in 1985 and 1986 and two times in 1987. Application time was determined by visually estimating the amount of johnsongrass foliage extending above cotton plants. Conventional boom treatments were applied three times in 1985, once in 1986, and twice in 1987, at or near the time of application with the tractor-mounted spot-sprayer. The volume of spray required for the 2-gallon hand and 'Spot Gun' treatments was measured for each plot.

Control of johnsongrass was determined by counting johnsongrass plants at various times during the year. Seedling johnsongrass plants (separated from rhizome plants based on a height difference) were counted in May each year from an area 1 foot wide by 10 feet long on a preselected row in each plot. Rhizome johnsongrass plants were counted in late season from an area 1 foot wide by 40 feet long on a preselected row in each plot. An additional johnsongrass control evaluation was made by visually estimating the percent control (0 = no control, 100 = complete kill) at mid-or late-season each year on the two center rows of each plot.

Cotton stand was determined by counting plants from one row in each plot. Seed cotton was mechanically harvested once each year from the two center rows in each plot.

Data were subjected to an analysis of variance. Means were separated using Duncan's multiple range test for significance at the 5% level of probability.

Results

Seedling johnsongrass

Treflan use in 1985 resulted in an average increase in johnsongrass control of 39.7% over the no Treflan plots (average 7.3 and 4.4 plants/row foot), based on plant counts made May 14 (Table 1). The respective values for 1986 and 1987 were 86.5% and 90.0% (average 11.1 and 1.5 plants/row foot in 1986, 11.1 and 1.1 plants/row foot in 1987). The average seedling

Table 1. The effect of SC 1084 or Select applied as spot treatments on seedling and rhizome johnsongrass populations. Delta Branch, Mississippi Agricultural and Forestry Experiment Station, Stoneville, MS.

Application [1]		Average johnsongrass plants/row foot[5]											
		Seedling Plants						Rhizome Plants					
	Herbicide rate (lb) or concentration	May 14, 1985		May 15, 1986		May 13, 1987		Oct. 4, 1985		Aug. 21, 1986		Aug. 6, 1987	
		Treflan		Treflan		Treflan		Treflan		Treflan		Treflan	
Method	(%)	−	+	−	+	−	+	−	+	−	+	−	+
		(No.)											
1 nozzle per row [2]	0.125 lb	13.6 a	2.9 bc	19.5 a	3.3 d	7.4 bcd	0.7 d	5.5 a	1.1 ab	0.7 c	0.1 c	0.3 e	0.0 e
2-gallon hand [3]	0.24%	9.8 ab	3.2 bc	8.0 bcd	1.6 d	16.4 ab	1.8 cd	5.6 a	2.7 ab	2.8 bc	0.3 c	4.8 c	0.6 e
2-gallon hand [3]	0.12%	7.6 abc	4.8 bc	17.2 ab	2.7 d	16.4 ab	1.9 cd	4.3 ab	2.7 ab	6.0 a	1.4 bc	7.8 b	2.3 de
Spotgun, 5 ml/squeeze [3]	0.24%	6.7 abc	4.4 bc	7.1 bcd	0.2 d	12.7 abc	1.4 cd	1.1 ab	2.9 ab	2.8 bc	0.5 c	4.4 cd	0.4 e
Spotgun, 10 ml/squeeze [3]	0.12%	3.0 bc	4.4 bc	7.7 bcd	0.3 d	10.3 a-d	0.4 d	0.8 b	1.6 ab	3.8 ab	0.1 c	10.5 a	0.9 e
Spotgun, 20 ml/squeeze [3]	0.06%	6.3 bc	2.4 c	15.5 abc	0.1 d	20.5 a	0.5 d	4.0 ab	1.1 ab	6.7 a	0.4 c	10.5 a	1.8 e
Tractor spot applicator [4]	0.125 lb	3.3 bc	8.9 abc	5.4 cd	3.5 d	2.1 cd	1.5 cd	1.0 ab	5.1 ab	0.7 c	0.3 c	0.0 e	0.0 e
Tractor spot applicator [4]	0.0625 lb	8.2 abc	3.8 bc	8.0 bcd	0.4 d	2.9 cd	0.7 d	1.8 ab	1.9 ab	1.0 c	0.2 c	0.3 e	0.0 e
Standard Error of Mean		2.1		3.2		3.5		1.3		1.0		1.1	
C.V (%)		63.2		89.2		98.6		86.3		79.8		69.6	

[1] Used SC 1084 4E in 1985, Select 2E in 1986 and 1987.

[2] Applied in 10 gallons/acre broadcast volume. Applied June 10, June 25, July 8, 1985; May 21, 1986; and May 22 and June 23, 1987.

[3] Applied June 10, 1985; June 17, 1986; and June 17, 1987.

[4] Applied in 10 gallons/acre broadcast volume when activated. Applied June 10, June 25, July 9, 1985; June 4, June 24, and July 21; and May 28 and June 23, 1987.

[5] Treflan 4E PPI 1.0 lb ai/A in 1985, and 0.75 lb ai/A in 1986 and 1987. Values within each date with the same letter are not different according to DMRT (P=0.05).

johnsongrass population in plots without Treflan increased 34% from 1985 to 1986 and remained stable from 1986 to 1987. The average johnsongrass population in Treflan-treated plots decreased 65% from 1985 to 1986 and further decreased 26% from 1986 to 1987.

Seedling johnsongrass control with multiple application treatments of Select in 1986 and 1987 differed only with the one nozzle per row treatment in 1986 when applied following Treflan compared with plots not receiving Treflan (Table 1). Seedling control in 1985 can only be compared between Treflan and no Treflan because other treatments were not applied until after May 14. On May 15, 1986, seedling johnsongrass control was greater in plots with Treflan with single application treatments of SC 1084 in 1985 using the 2-gallon hand treatment at 0.12% v/v and the "Spot Gun" at 0.06% v/v. Single application treatments made in 1986 resulted in less seedling johnsongrass on May 13, 1987 with Treflan with all treatments except with Select when applied in the "Spot Gun" at 0.12% and 0.24% v/v.

Rhizome johnsongrass

In early October 1985, the average increase in rhizome johnsongrass control with SC 1084 treatments following Treflan was 20% (average 3.0 and 2.4 plants/row foot) (Table 1). Respective values for increased johnsongrass control with Select in 1986 and 1987 were 87% and 83% (average plants per row foot were 3.1 and 0.4 in 1986, and 4.8 and 0.8 in 1987). The average rhizome johnsongrass population increase in treatments without Treflan from 1985 to 1986 was 3%, and from 1986 to 1987 was 55%. With treatments following Treflan, average rhizome johnsongrass populations decreased 83% from 1985 to 1986 but increased 50% from 1986 to 1987.

Johnsongrass control in all treatments with SC 1084 in 1985 following Treflan did not differ from those without Treflan (Table 1). Without Treflan, the number of rhizome johnsongrass plants was less with SC 1084 at 0.12% in the 'Spot Gun' than at 0.24% with the 2-gallon hand or the one-nozzle-per-row treatments. Multiple application treatments with Select in 1986 and 1987 without Treflan provided equal rhizome johnsongrass control to comparable treatments with Treflan. In 1986, single applications of Select with the 2-gallon hand treatment at 0.12% and the "Spot Gun" treatment at 0.12% resulted in more rhizome johnsongrass plants in late August without Treflan than with those treatments applied following Treflan. All single application spot treatments of Select in 1987 following Treflan had fewer rhizome johnsongrass plants in early August than those without Treflan.

Visual rhizome johnsongrass control in July or September with spot treatments of SC 1084 or Select following Treflan averaged 22%, 40%, and 16% greater than the same treatments without Treflan for 1985, 1986, and 1987, respectively (Table 2). SC 1084 or Select treatments that did not show visual control differences from Treflan were (1) one-nozzle-per-row in all years, (2) the 2-gallon hand treatments with Select at 0.12 and 0.24% v/v in 1987, (3) "Spot Gun" treatments at 0.24% v/v 5 ml/squeeze in 1985 with SC 1084 and in 1987 with Select, (4) "Spot Gun" treatments with SC 1084 at 0.12% v/v 10 ml/squeeze and at 0.06% v/v 20 ml/squeeze in 1985, and (5) the tractor-mounted device with SC 1084 or Select at 0.0625 and 0.125 lb ai/A in all years.

Spray volume

The spray volume required to spot treat johnsongrass plants by hand

Table 2. The effect of SC 1084 or Select applied as spot treatments on visual rhizome johnsongrass control. Delta Branch, Mississippi Agricultural and Forestry Experiment Station, Stoneville, MS.

Application[1]	Herbicide rate (lb) or concentration (%)	Estimated Visual Johnsongrass Control[5]					
		July 16, 1985		September 3, 1986		July 24, 1987	
Method		− Treflan	+ Treflan	− Treflan	+ Treflan	− Treflan	+ Treflan
		(%)					
1 nozzle per row [2]	0.125 lb	58 ab	82 a	82 a	95 a	90 abc	97 a
2-gallon hand [3]	0.24%	45 bc	82 a	40 bc	87 a	73 cd	90 abc
2-gallon hand [3]	0.12%	13 c	70 ab	13 cd	70 ab	60 d	60 d
Spotgun, 5 ml/squeeze [3]	0.24%	68 ab	80 ab	38 bc	90 a	68 cd	82 bcd
Spotgun, 10 ml/squeeze [3]	0.12%	72 ab	82 a	30 cd	88 a	30 e	72 cd
Spotgun, 20 ml/squeeze [3]	0.06%	53 ab	90 a	7 d	87 a	30 e	72 cd
Tractor spot applicator [4]	0.125 lb	87 a	87 a	93 a	95 a	94 ab	95 ab
Tractor spot applicator [4]	0.0625 lb	90 a	92 a	79 a	97 a	93 ab	97 a
Standard Error of Mean		10.3		9.9		7.1	
C.V. (%)		24.9		25.2		16.4	

[1] Used SC 1084 4E in 1985, Select 2E in 1986 and 1987.

[2] Applied in 10 gallons/acre broadcast volume. Applied June 10, June 25, July 8, 1985; May 21, 1986; and May 22 and June 23, 1987.

[3] Applied June 10, 1985; June 17, 1986; and June 16, 1987.

[4] Applied in 10 gallons/acre broadcast volume when activated. Applied June 10, June 25, July 9, 1985; June 4, June 24, and July 21, 1986; and May 28 and June 23, 1987.

[5] Treflan 4E PPI 1.0 lb ai/A in 1985, and 0.75 lb ai/A in 1986 and 1987. Values within each date with the same letter are not different according to DMRT (P=0.05).

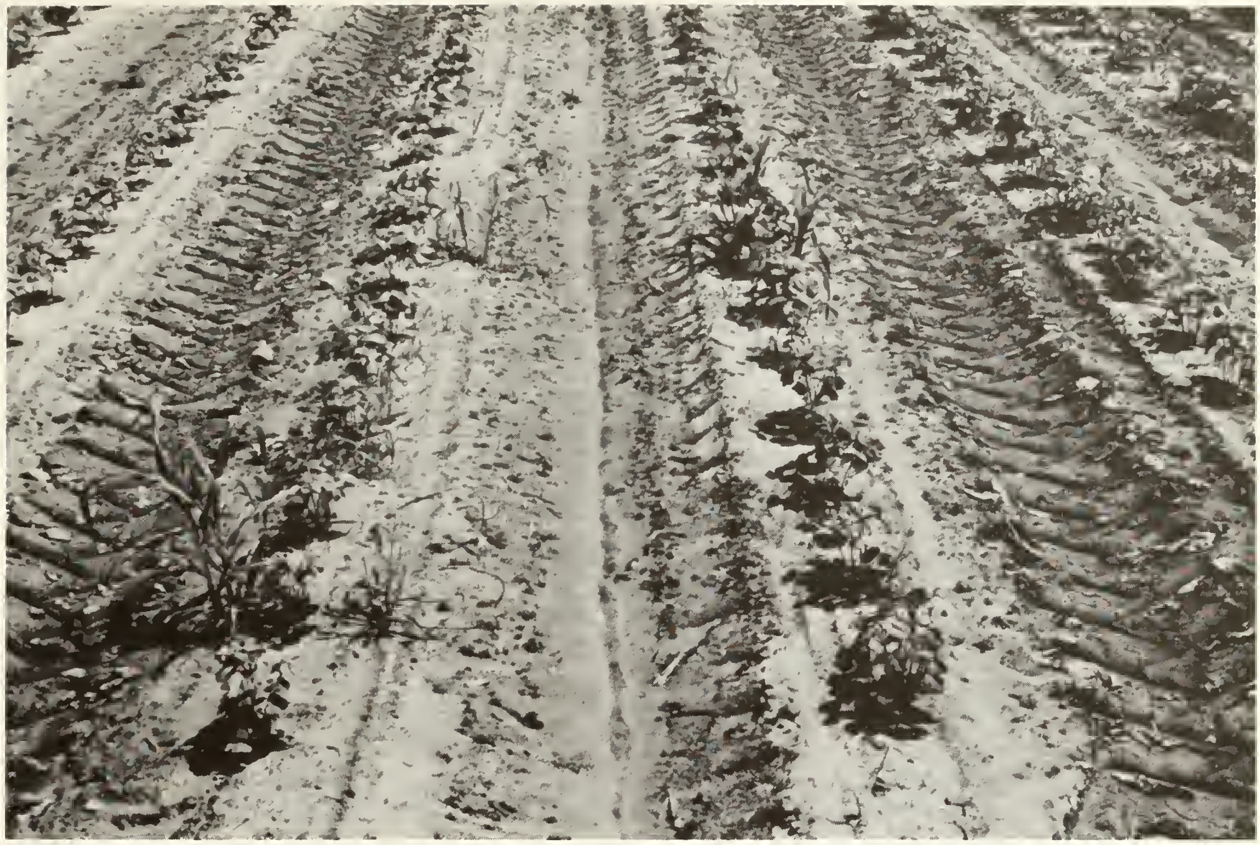
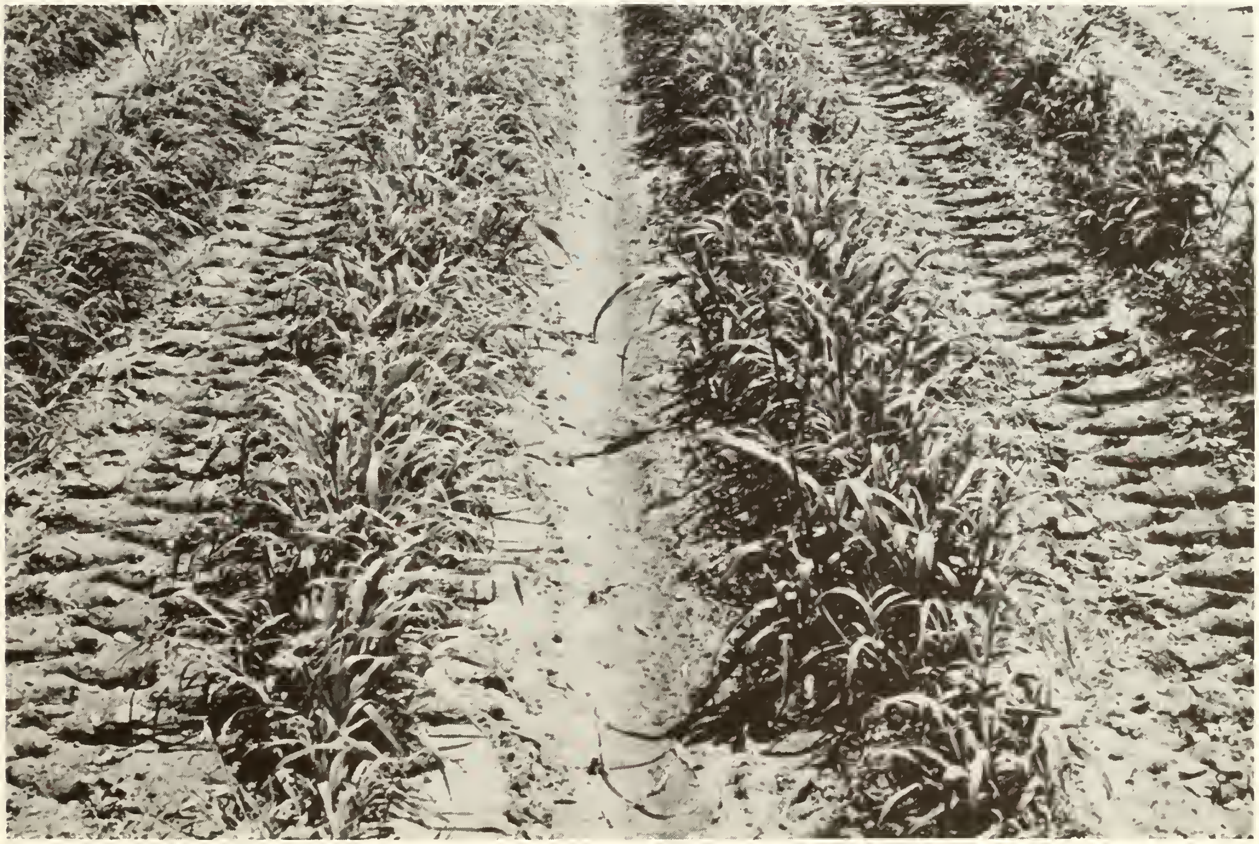


Figure 3. Both plots shown here had SC 1084 applications in 1985. The plot above was treated with Treflan PPI, the plot below was not treated with Treflan PPI. Plots were photographed May 21, 1986.



averaged 1.8, 4.3, and 2.3 times more without Treflan than with the same treatments applied after the use of Treflan for 1985, 1986, and 1987, respectively (Table 3). Volume ranged from a low of 6.9 gal/A in 1985 with the 2-gallon hand application of SC 1084 at 0.24% v/v with Treflan to a high of 208.8 gal/A in 1986 with the 2-gallon hand application of Select at 0.12% v/v without Treflan.

Cotton response

Cotton stand was not affected by any treatment during the course of this study (data not presented). In 1985, seed cotton yields in plots treated with the 2-gallon hand treatment at 0.12% v/v SC 1084 without Treflan were lower than those treated with the 2-gallon hand treatment at 0.24% v/v with Treflan, the "Spot Gun" treatment at 0.12% with Treflan, and the tractor-mounted spot treatment of 0.0625 lb ai/A with Treflan (Table 4). The yields were lower in the SC 1084 treatment applied with one nozzle per row without Treflan than the treatment with the 2-gallon hand sprayer at 0.24% v/v with Treflan.

In 1986, cotton yields from Select treatments using the tractor-mounted spot sprayer were not compared to the other treatments because the spray mix-

Table 3. Spray volume used in spot treating johnsongrass by hand. Delta Branch, Mississippi Agricultural and Forestry Experiment Station, Stoneville, MS.

Application [1]		Spray Volume Used [2]					
	Herbicide	June 10, 1985		June 17, 1986		June 16, 1987	
Method	concentration	− Treflan	+ Treflan	− Treflan	+ Treflan	− Treflan	+ Treflan
	(%)	(Gallons/Acre)					
2-gallon hand	0.24	29.5 bcd	6.9 d	115.3 bc	22.5 d	64.6 a	20.5 b
2-gallon hand	0.12	20.8 cd	14.0 cd	208.8 a	63.1 cd	64.6 a	27.5 b
Spotgun, 5 ml/squeeze	0.24	54.2 ab	35.5 bcd	90.3 bc	30.4 d	34.6 b	27.8 b
Spotgun, 10 ml/squeeze	0.12	28.7 bcd	37.5 bc	100.1 bc	22.8 d	38.1 b	16.0 b
Spotgun, 20 ml/squeeze	0.06	79.7 a	22.8 cd	135.9 b	13.0 d	59.9 a	22.9 b
Standard Error of Mean		8.7		17.1		7.3	
C.V. (%)		45.5		36.9		33.6	

[1] Used SC 1084 4E in 1985, Select 2E in 1986 and 1987. Applied June 10, 1985; June 17, 1986; and June 16, 1987.

[2] Treflan 4E PPI 1.0 lb ai/A in 1985, and 0.75 lb ai/A in 1986 and 1987. Values within each date with the same letter are not different according to DMRT (P=0.05).

Table 4. The effect of johnsongrass control with SC 1084 or Select applied as spot treatments on seed cotton yield. Delta Branch, Mississippi Agricultural and Forestry Experiment Station, Stoneville, MS.

Application	Herbicide rate (lb) or concentration (%)	Seed Cotton Yield[5]					
		1985		1986		1987	
Method		− Treflan	+ Treflan	− Treflan	+ Treflan	− Treflan	+ Treflan
		(Pounds/Acre)					
1 nozzle per row [1]	0.125 lb	1,606 bc	2,167 abc	1,605 ab	1,350 abcd	2,432 ab	2,736 a
2-gallon hand [3]	0.24%	2,195 abc	2,494 a	1,539 abc	1,725 a	331 c	2,464 ab
2-gallon hand [3]	0.12%	1,590 c	2,069 abc	536 d	1,319 abcd	201 c	1,720 b
Spotgun, 5 ml/squeeze [3]	0.24%	2,391 abc	2,396 abc	1,067 abcd	1,717 a	518 c	2,137 ab
Spotgun, 10 ml/squeeze [3]	0.12%	2,238 abc	2,418 ab	780 bcd	1,519 abc	416 c	2,230 ab
Spotgun, 20 ml/squeeze [3]	0.06%	2,140 abc	2,347 abc	682 cd	1,462 abc	58 c	2,308 ab
Tractor spot applicator [4]	0.125 lb	2,352 abc	2,347 abc	927 abcd[6]	1,125 abcd [6]	2.781 a	2,779 a
Tractor spot applicator [4]	0.0625 lb	1,944 abc	2,418 ab	723 abcd[6]	994 abcd[6]	2.161 ab	2,494 ab
Standard Error of Mean		237.9		269.9		295.8	
C.V. (%)		18.8		39.2		29.5	

[1] Used SC 1084 4E in 1985, Select 2E in 1986 and 1987.

[2] Applied in 10 gallons/acre broadcast volume. Applied June 10, June 25, July 5, 1985; May 21, 1986; and May 22 and June 23, 1987.

[3] Applied June 10, 1985; June 17, 1986; and June 16, 1987.

[4] Applied in 10 gallons/acre broadcast volume when activated. Applied June 10, June 25, July 9, 1985; June 4, June 24, July 21, 1986; and May 28 and June 23, 1987.

[5] Treflan 4E PPI 1.0 lb ai/A in 1985, and 0.75 lb ai/A in 1986 and 1987. Values within each date with the same letter are not different according to DMRT (P=0.05).

[6] Yields reduced by cotton injury on July 21 from accidental spray contamination.

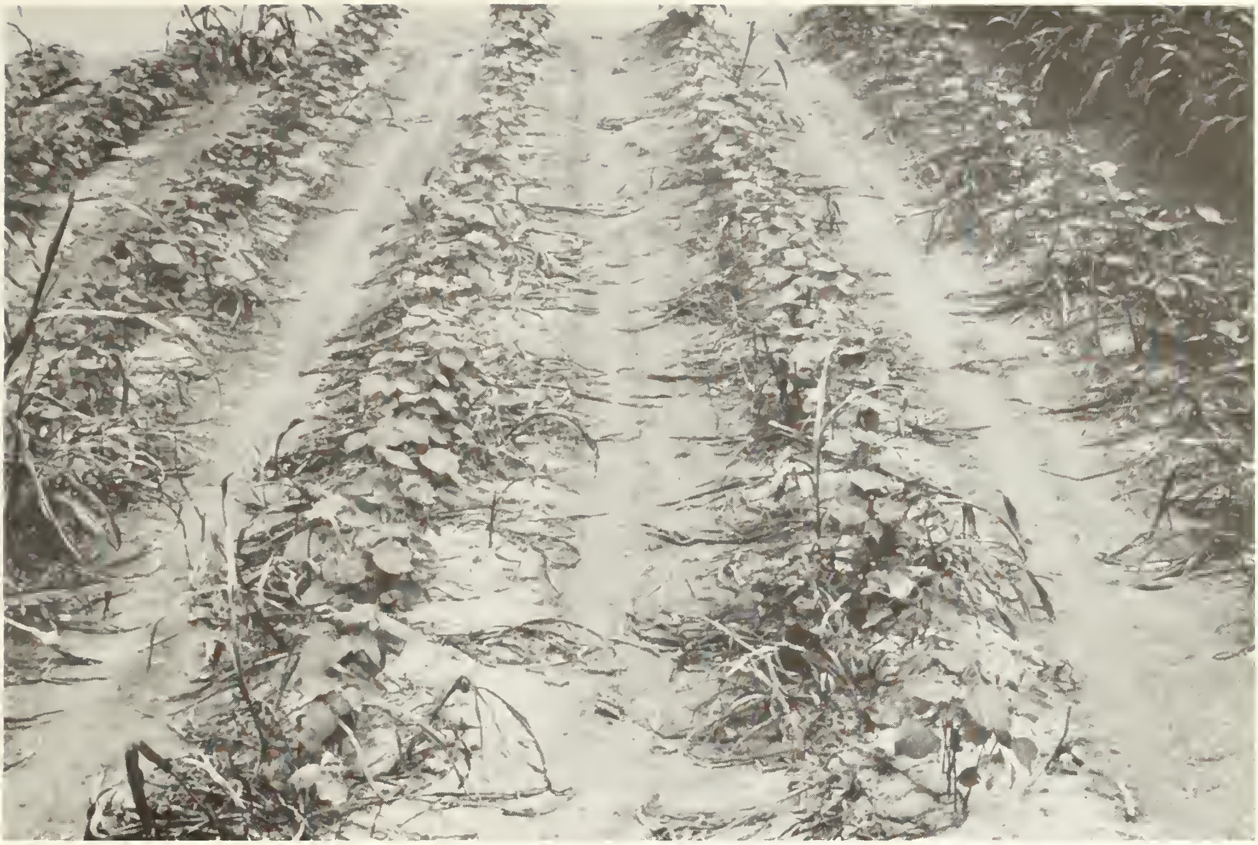


Figure 4. Both plots pictured here were treated with SC 1084 in 1985, and with Select in 1986 and 1987 using one nozzle per row. Photograph above taken June 1, 1987, shows effect on johnsongrass. Photograph below taken July 16, 1987 shows very little regrowth of treated johnsongrass plants.

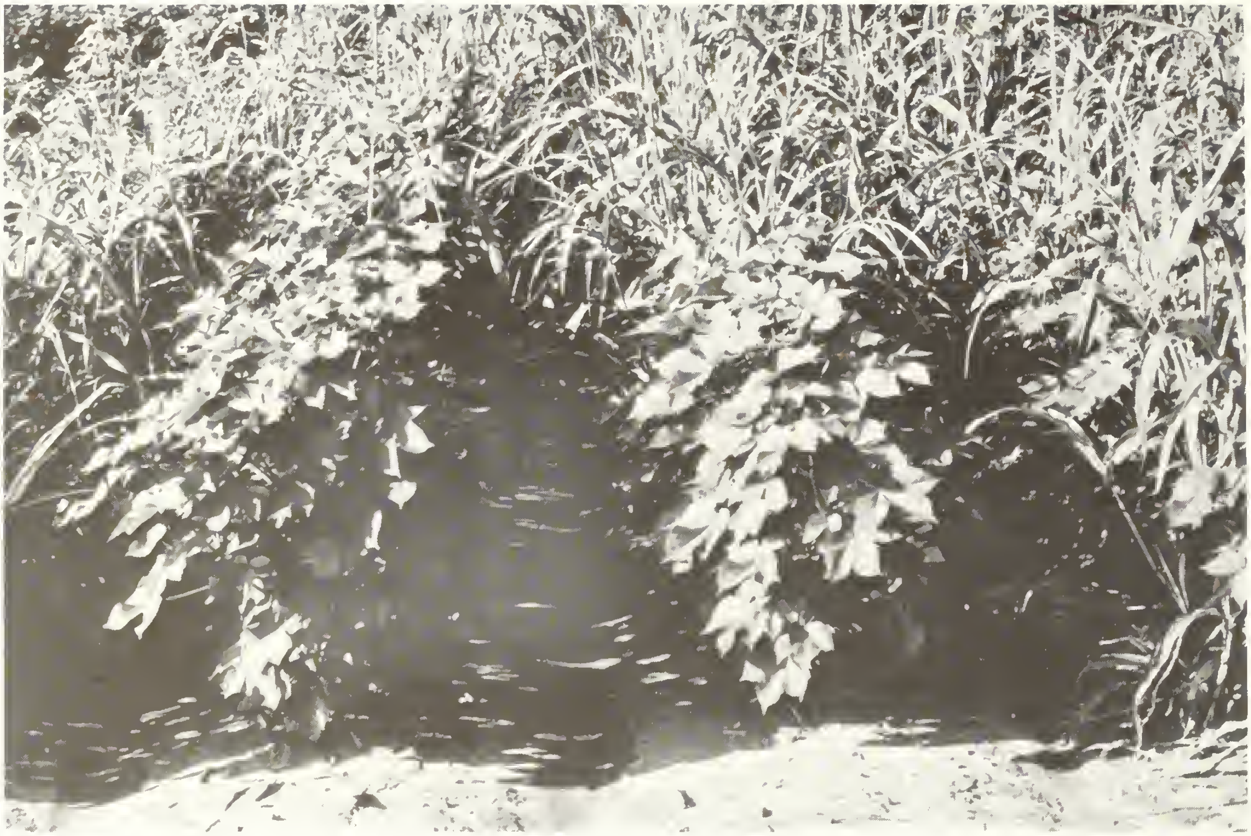
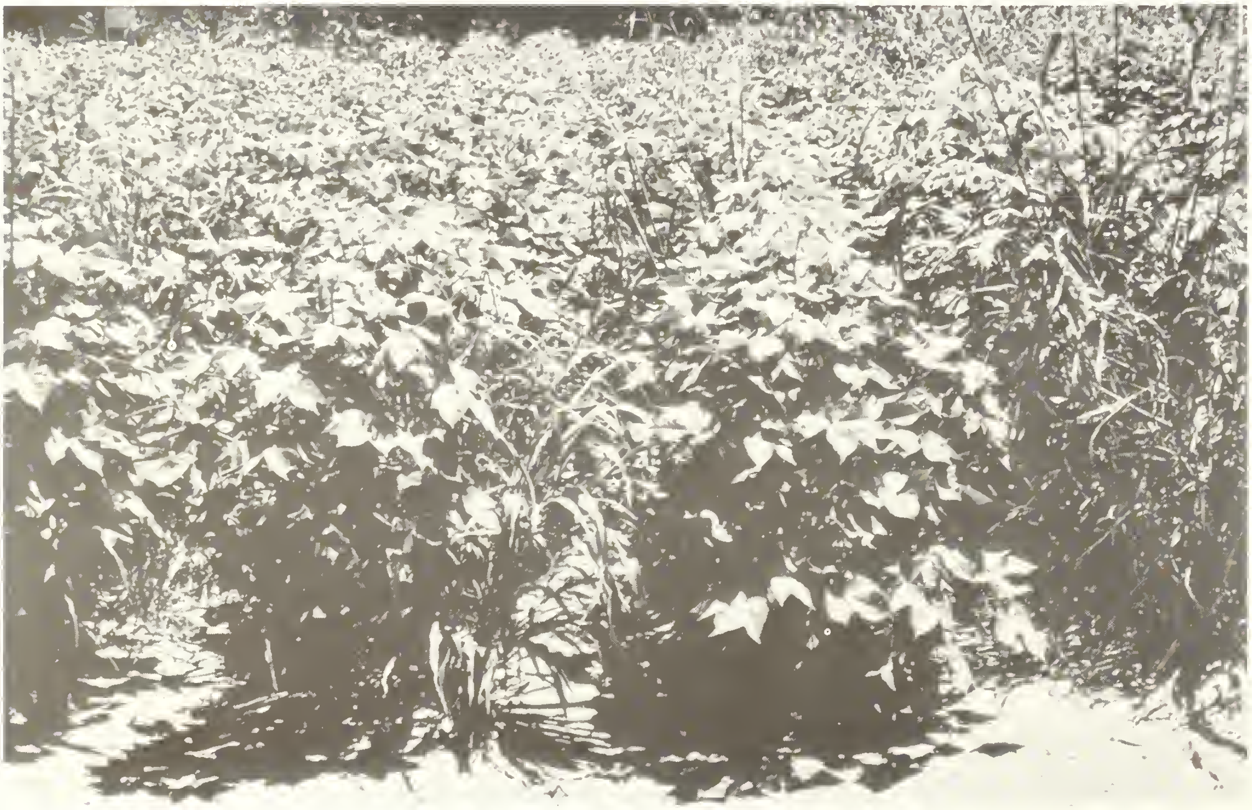


Figure 5. The plot above was treated with Treflan PPI plus a single "Spot Gun" application of SC 1084 or Select 1985-1987. The plot below was spot treated with multiple applications of SC 1084 or Select with the tractor-mounted sprayer 1985-1987. The photographs were taken in late July 1987.



ture at the second application date was accidentally contaminated with imazaquin resulting in cotton injury.

Cotton yields were less with Select applied with the 2-gallon hand treatment at 0.12% v/v without Treflan when compared with all of the "Spot Gun" and the 2-gallon hand treatment at 0.24% v/v with Treflan. With the "Spot Gun" treatment at 0.06% v/v without Treflan, cotton yields were less than the "Spot Gun" at 0.24% v/v and 2-gallon hand at 0.24% v/v treatments with Treflan. The cotton yields in 1987 were less when Select was applied without Treflan when compared with spot treatments with Select following Treflan, except for those applied with the tractor-mounted spot sprayer (Table 4). The one-nozzle per-row treatment with Select without Treflan produced similar yields to those obtained with Treflan.

The performance of the tractor mounted spot sprayer was satisfactory during each year. The efficiency of the system was ≥ 95% in detecting the presence of johnsongrass that was taller than the cotton. When activated, the three nozzle arrangement provided adequate coverage of the johnsongrass plants.

Summary

The conventional boom and tractor-mounted spot sprayer provided excellent johnsongrass control. Initial control was maintained through the season with repeated applications. Hand-held application techniques using one treatment each season resulted in the need for preplant incorporated applications of Treflan for effective johnsongrass control and acceptable cotton yields. The use of Select in 1986 and 1987 was very effective for control of johnsongrass, especially with multiple applications —and multiple application treatments did not require prior use of Treflan. Single application spot treatments following Treflan, which gave excellent control (<0.6 plant/foot) of johnsongrass at late-season, were Select at 0.24% v/v applied with a 2-gallon hand sprayer and all "Spot Gun" treatments in 1986 and at 0.24% v/v (5 ml) with a "Spot Gun" in 1987.

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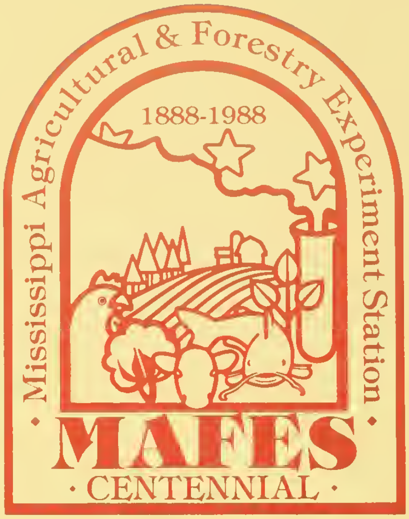
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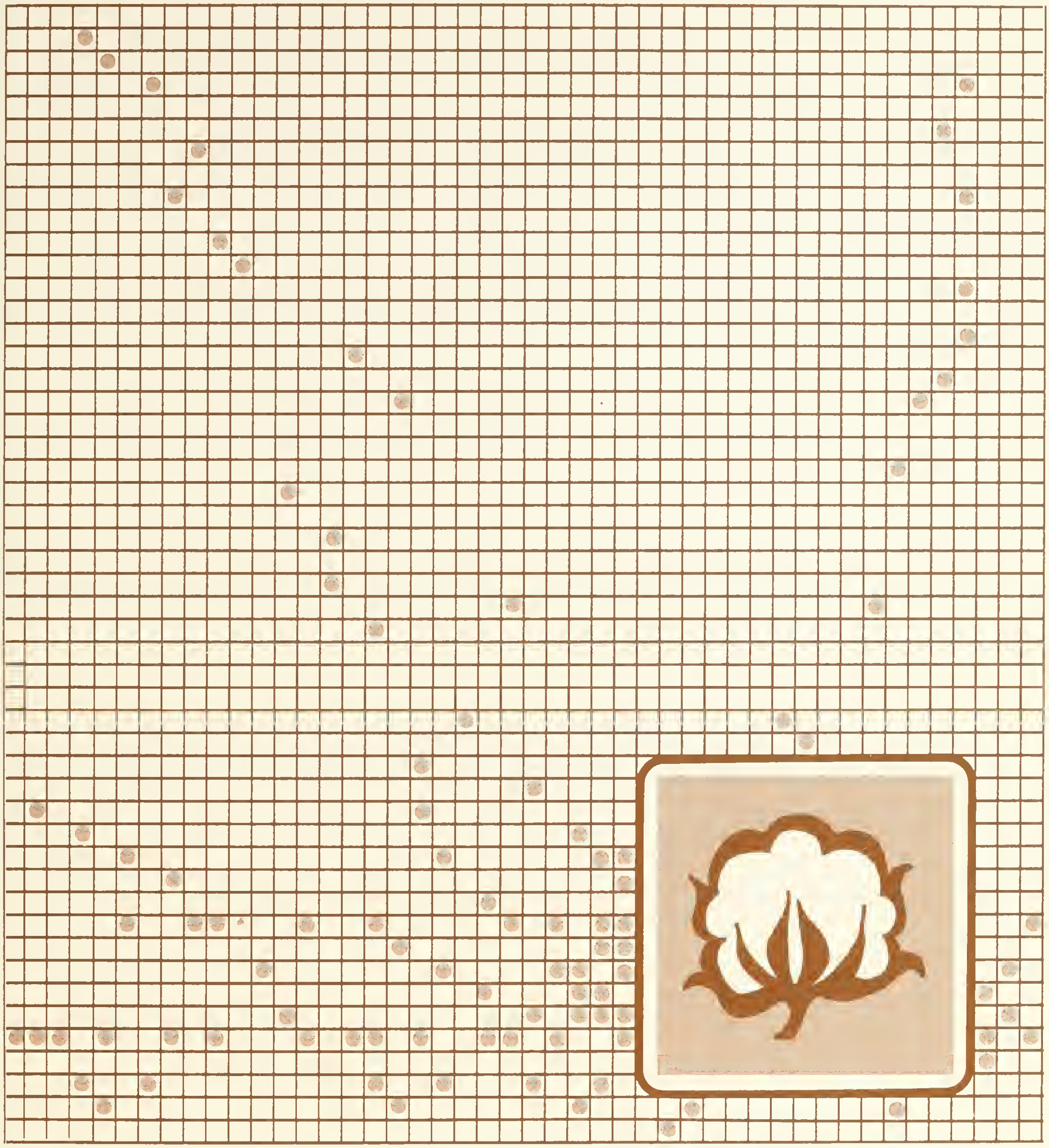

Herbicide Application Technology in Mississippi Cotton

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Herbicide Application Technology in Mississippi Cotton

Introduction

Following the introduction of 2,4-D in 1945, dalapon was introduced in 1953, and diuron was introduced in 1954 (1). Other herbicides introduced prior to 1965 include DSMA, paraquat, linuron, trifluralin, and fluometuron. Some of these herbicides became extensively used in cotton to reduce the strong dependence on hand labor (5).

Selectivity (if present) of these compounds was an inherent property of the compound or was achieved by placement or precise delivery of the compound to the target. For example, diuron provided excellent preemergence weed control in cotton, but also could be used postemergence with the addition of a surfactant (8). Without selectivity to cotton, precise placement was necessary to prevent excessive crop injury. Equipment with parallel action mounting so that nozzles were positioned at a constant height and angle was designed to aid in herbicide placement (6).

Soil incorporation was another revolutionary procedure that evolved during the early 1960's. Because trifluralin and other dinitroanilines were volatile and photodegradable, considerable loss occurred with surface preemergence sprays. Thus, these were applied preplant and incorporated into the soil. The new application method resulted in consistently higher levels of weed control with less dependence upon rainfall than the conventional preemergence treatments. A burst of activity followed with the development of all kinds of equipment for soil incorporation. The conventional disk harrow was readily available, but new equipment ranged from many types of ground-driven incorporators to power tillers.

The first significant increase in the use of aerial application for herbicides in cotton came about with the broadcast preplant use of dinitroanilines. Wide disk harrows or field cultivators followed closely behind the herbicide application to prevent losses from volatilization. In this manner, large acreages were treated rather quickly. Aerial application using spray volumes of 3 to 5 gallons per acre are now standard, but ultra-low volumes (ULV) of 1 quart per acre or less are possible (9).

Innovative ideas have evolved over the years in order to make use of products that are non-selective. The recirculating sprayer was first developed in 1964 for spraying crops where weeds were taller than the crop (10). Chandler et al. (3) used activated charcoal to protect cotton from high rates of diuron.

The introduction of glyphosate in 1974 stimulated a great deal of interest in obtaining selectivity with this compound due solely to placement. The shielded sprayer was developed by Jordan in 1978 (7). The most widely used system was the ropewick applicator developed by Dale (4).

Weed scientists as a group have long recognized the need for improved application methodology because of experience with problems associated with calibration, getting the herbicide on target, and other factors which result in poor performance. The objective is optimum efficacy coupled with minimum cost per unit of production.

Producers' needs are the prime objective of research. Thus, their opinions are sought by weed scientists involved in application technology. Until more selective herbicides are discovered, current application technology must be used more efficiently. The objective of this report is to define major areas of herbicide application technology and identify present problems and future needs.

Materials and Methods

During the fall of 1987, a survey was mailed to approximately 70 farmers, consultants, extension workers, and research personnel. Of the 23 respondents (33% of total) 20 were farmers (19 Delta, 1 non-Delta), one was a state researcher, one was a consultant, and one was not identifiable. Ten of the 20 farmers reported acreages exceeding 20,000 acres. Assuming an average farm size of 500 acres for the remaining 10, the survey covers some 25,000 acres of cotton at some 17 locations, mainly within the Delta (Figure 1).

Equipment descriptions as described by Barrentine (2) were mailed along with each survey so that identification of certain pieces of equipment could be standardized. The survey was divided into three major categories or parts. The first asked the question *"What percent of the cotton acreage on your farm (or in your state) receives . . .?"* The various categories given were as follows:

A. Preplant foliar (PPF) or "burn down" herbicides ______%

B. Preplant incorporated (PPI) herbicides ______%
    Band ______%
    Broadcast ______%

C. Preemergence (PRE) surface herbicides ______%
    Band ______%
    Broadcast ______%

D. Postemergence (POT) over-the-top ______%
    Band ______%
    Broadcast ______%
    Spot ______%

E. Post-directed sprays (PDS) ______%
    Band ______%
    Broadcast ______%

F. Layby (LBY) ______%
    Band ______%
    Broadcast ______%

The second part asked the question *Of the PPI applications on your farm (or in your state), what percent is applied with:* where the categories were given as follows:

A. Ground-driven equipment ______%
  1. Tractor mounted sprayer attachment______%
  2. Hi boy, spray coupe, etc. ______%
  3. Planter attachment ______%
  4. Other ______%

B. Fixed wing aircraft ______%

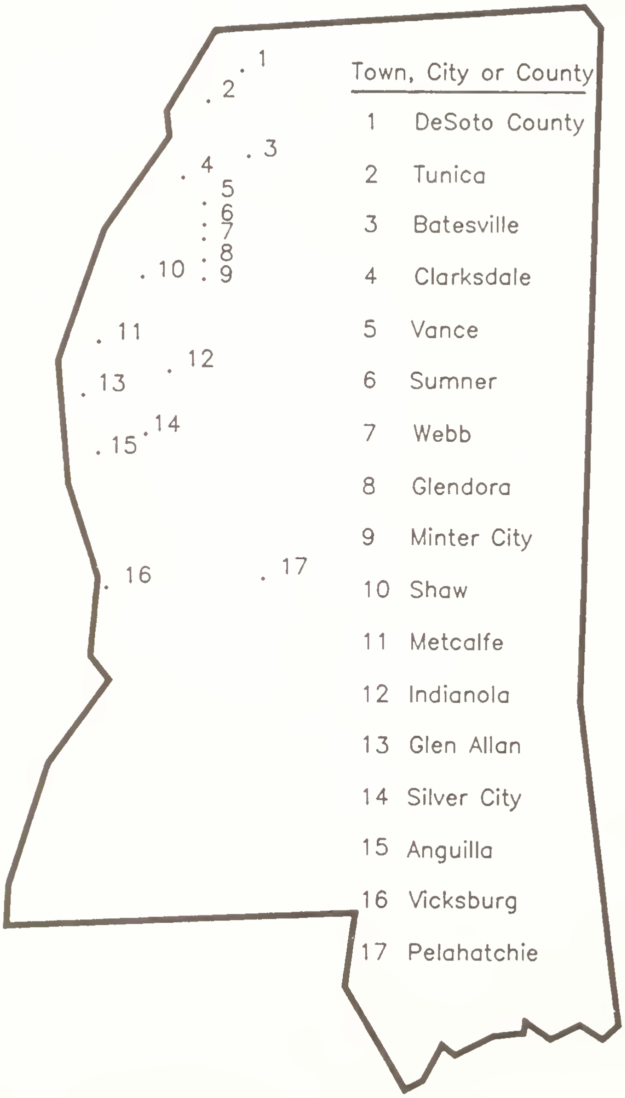
These same responses were asked for after replacing "PPI" in the above with "PRE" or "POT," yielding three segments to this section of the survey.

The final section asked the question *Incorporation of dinitroanilines and other such herbicides is done with . . . ?* The choices given are covered in Figures 5 through 10. For clarity, descriptions of various types of incorporation equipment were included in each survey. These descriptions are provided in Table 1. Although 23 responses were returned, not all categories had a response. The number of responses ranged from 20 to 23 for Part I, 16 to 23 Part II, and 6 to 21 for Part III.

Results and Discussion

Only 3% of the cotton acreage reported received some sort of PPF treatment (Figure 2), indicating very little stale seedbed planting— probably due to raised beds required for adequate stand establishment and positive yield response from subsoiling.

Ninety-eight percent of the acreage received a PPI herbicide, of which 33% was applied in a band and the remain-



Town, City or County	
1	DeSoto County
2	Tunica
3	Batesville
4	Clarksdale
5	Vance
6	Sumner
7	Webb
8	Glendora
9	Minter City
10	Shaw
11	Metcalfe
12	Indianola
13	Glen Allan
14	Silver City
15	Anguilla
16	Vicksburg
17	Pelahatchie

Figure 1. Distribution of responses to "Herbicide Application Techniques for Mississippi Cotton" survey, Fall 1987.

Table 1. Equipment description of devices used for soil incorporating herbicides, (Adapted from Barrentine, 1988).

Tandem disk harrows (four-gang). Types are: (1) Finishing disk, spherical blades, spaced <8 inches apart, <20 inches in diameter; (2) Combination disk, spherical, or conical blades, spaced 8 to 9 inches apart, 20 to 24 inches in diameter; (3) Cutting disk, spherical or conical blades, spaced >9 inches apart, >24 inches in diameter. Blades may be notched or not.

Field cultivators are equipped with spring steel shanks which have an integral forged point or mounting holes for replaceable sweeps. Sweeps may be 2 inch chisel points or 5 to 12-inch shovel sweeps. The shanks are generally spaced 6 to 9 inches and stagger-mounted on two or more rows. The "C" shanks can be rigid or spring (loaded) mounted.

Flexible shank cultivators (Danish S-Tine cultivators). The S-Tine or shanks may be coiled-S or S shaped. The spring steel shanks are usually lighter in weight than the field cultivators and are stagger-mounted on 2 or more rows. Sweeps may be small ¾-inch chisel or 2½-inch "goosefoot" sweeps.

Power-driven (PTO) tillers are tractor-mounted, PTO-driven and of three types; (a) *vertical-action* in which the tines (blades) ("L," "C," or straight shaped of various lengths) rotate about a transverse axis to the direction of tractor travel, (b) *horizontal-action* tillers in which tapered spikes rotate and 'stir' the soil in complete circles or oscillate, (c) *combination-action* tillers in which tapered spikes engage the soil with both vertical and horizontal action.

Spike/spring (tine) tooth harrows are drag harrows of two types, the spike tooth and the coil-tine harrow (often called spring tooth cultivator, tine-tooth harrow).

Ground-driven devices are of several designs and include the rolling cultivator (Lilliston), open-steel-mesh-wheel (Gandy-Ro-Wheel), rotary hoes, etc. The rolling cultivator consists of gangs of ground-driven tine wheels with curved, twisted blades radiating from the center as spokes on a wheel. The open steel mesh wheel is constructed of about 2-inch open steel mesh rolled and welded into a wheel. Rotary hoes are similar in design to the rolling cultivator except the tines are curved, rounded, tapering to a point (spiker tines). These have long been used to break the soil crust to aid in crop emergence and destroy small emerging seedling weeds. Other tine shapes are also used.

Combination tools (seedbed conditioners) are two or more tillage devices used in combination on the same implement. Various combinations of a ground driven rotary spiral cutter reel, spike tooth harrow, drag board or plank, field cultivator, disk gangs, coil-tined harrow, flexible shank cultivator (Danish or S-Tine harrow), rolling cultivator gangs, rotary hoe gangs, or power-tillers can be implemented.

ing portion was broadcast. Less than 3% of this was applied by air (Figure 3), which indicated that interest in aerial application of these compounds was not as prevalent as during the 1960's and early 1970's (2).

Preemergence surface applications were applied to 100% of the cotton acreage, with 99% applied in a band (Figure 2). Aerial preemergence applications were less than 1% (Figure 3). The minor use of broadcast preemergence application is probably due to economics.

Less than one-third of the cotton acreage in the Mississippi Delta received a post-emergence-over-the-top (POT) treatment (Figure 2). This method constituted the highest percentage of aerial application, with 10% being applied with fixed wing aircraft (Figure 3). Of the 31% of POT-treated acreage, 64% was spot treated, 18% was band treated, and 18% was broadcast treated (Figure 2). The lack of selective broadleaf compounds for POT use in cotton was reflected by these numbers. Also, the large percentage of spot treatments reflect the widespread economical use of sethoxydim or fluazifop. These two compounds probably also make up a portion of the 36% of band and/or broadcast treatments.

Due largely to the lack of selective broadleaf POT compounds, 81% of the cotton acreage received a PDS treatment, of which 99% was applied in a band (Figure 2). These numbers were indicative of the widespread use of band applications for PRE treatments. Applying an herbicide in a band, in most cases, dictates that a second weed control measure will be necessary to alleviate weed problems in the untreated portion of the row. Also, available herbicides are less than 100% effective, and this makes a PDS application necessary.

Seventy-nine percent of the cotton acreage reported, received a LBY treatment of which 80% was broadcast (Figure 2). Apparently, late-emerging weeds were prevalent in sufficient quantities to warrant an extended weed control program. PDS and LBY treatments were both approximately 80%, which suggests that these two systems were used in combination.

Figure 4 provides an illustration of how PPI, PRE, and POT applications were applied by ground. PPI applications were made 89% of the time with a tractor-mounted sprayer. This allowed the use of an incorporating device along with the sprayer to eliminate one trip across the field. Due to the prevalence of band applications, 60% of the PRE treatments were applied with a planter-attachment, which enables the producer to plant and spray at the same time. Tractor-mounted sprayers were used 39% of the time, while high clearance equipment was used 1% of the time.

POT applications were applied 57% of the time with tractor-mounted sprayers, 35% of the time with spot sprayers, and 4% each for high clearance equipment and ropewick applicators. Introduction of sethoxydim and fluazifop has apparently reduced the application of glyphosate by ropewick applicators. These compounds are very selective and eliminate the need for slow precise application necessary for a nonselective herbicide such as glyphosate.

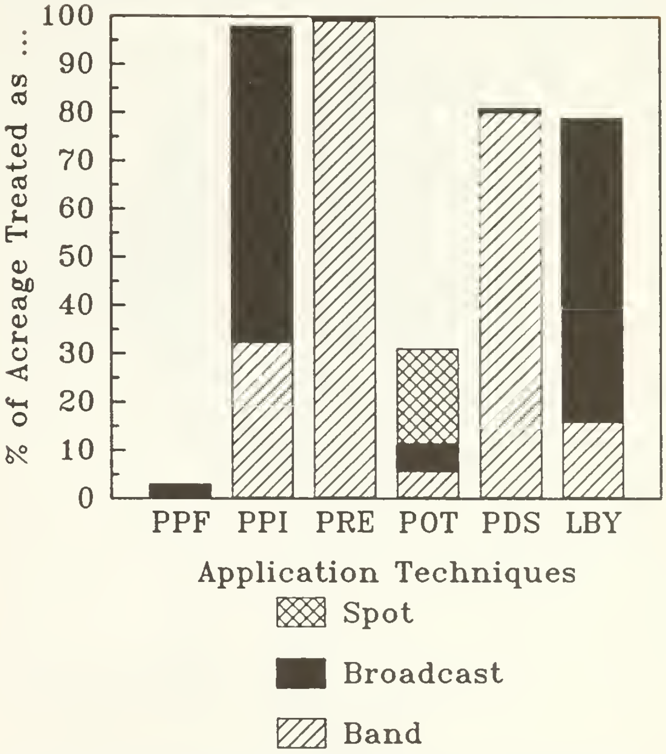


Figure 2. Percent of cotton acreage treated as preplant foliar (PPF), preplant incorporation (PPI), preemergence (PRE), postemergence over-the-top (TOP), post-directed spray (PDS) and layby (LBY) treatments in Mississippi, 1987.

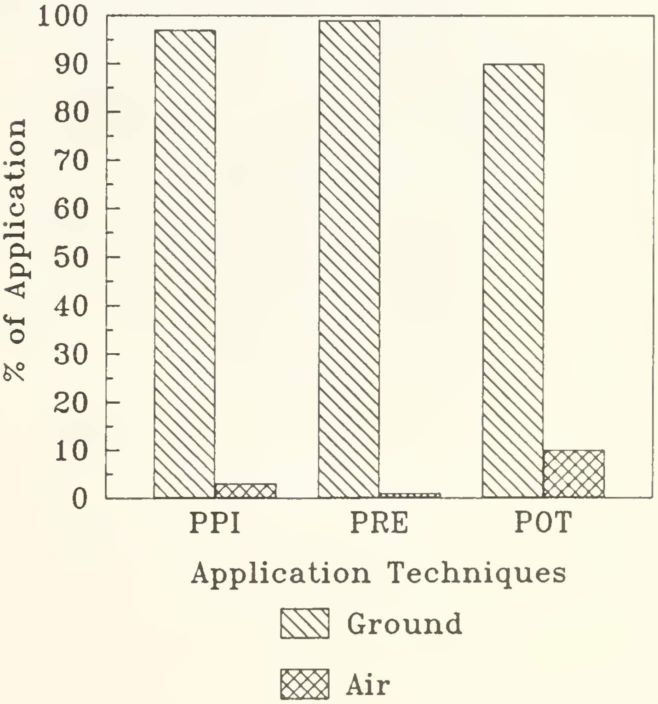


Figure 3. Distribution of ground versus air application of herbicides applied in cotton as PPI, PRE or POT treatments in Mississippi, 1987.

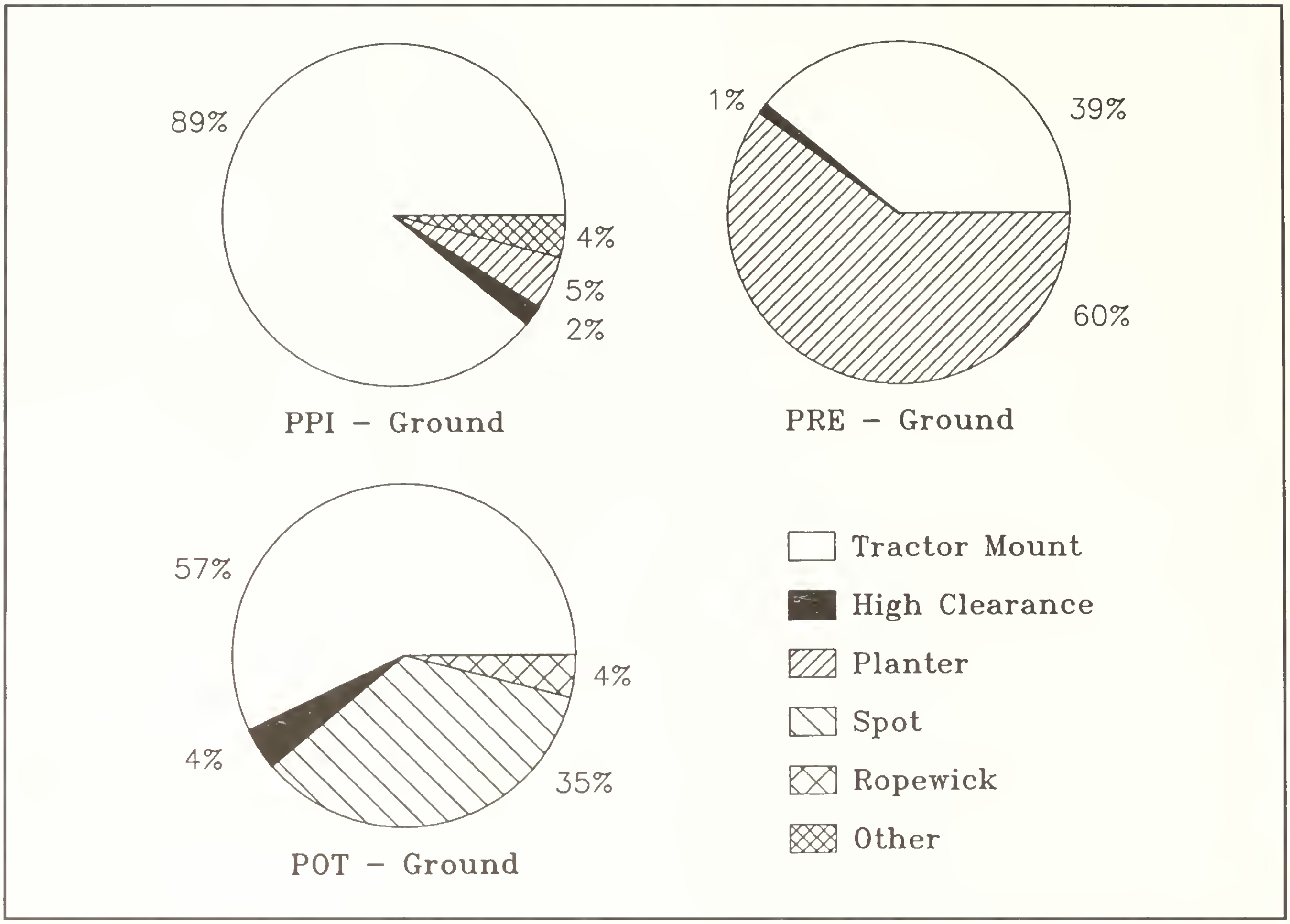


Figure 4. Distribution of how herbicides are applied in cotton by ground equipment in Mississippi, 1987.

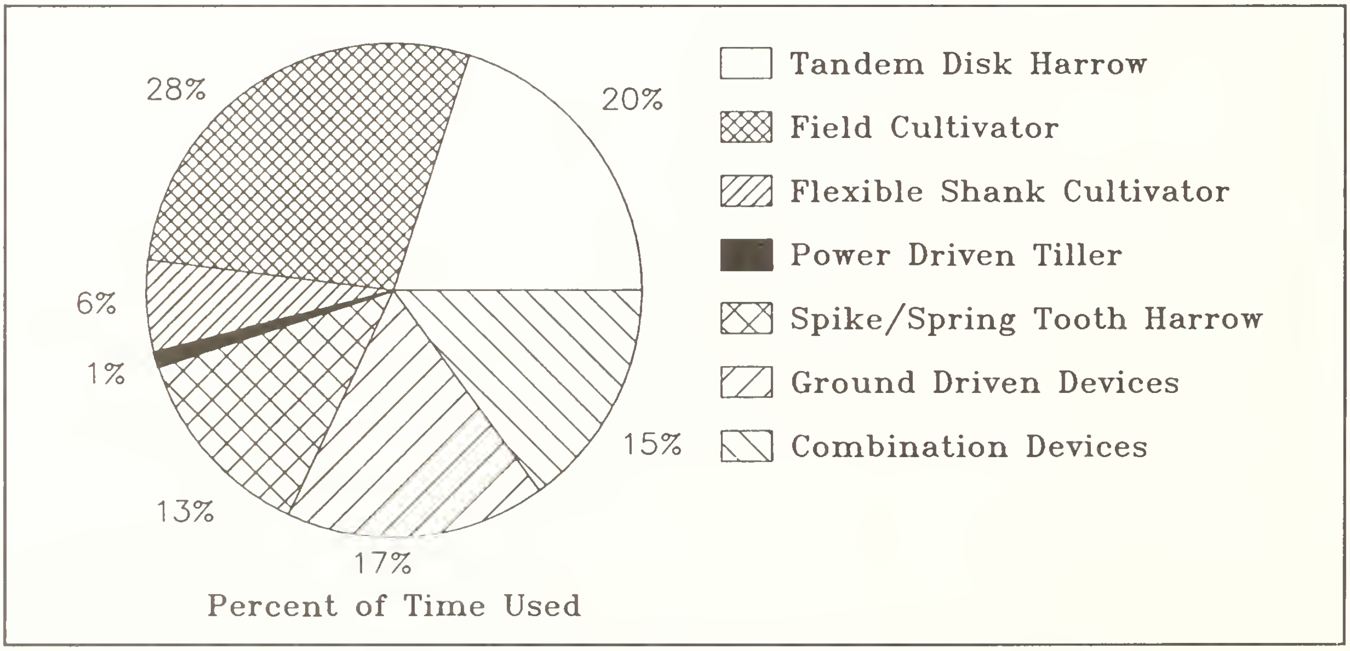


Figure 5. Producer preference of devices used to incorporate cotton herbicides in Mississippi, 1987.

Nearly half of all soil incorporation was done with either a tandem disk or field cultivator, with each type having a 20% and 28% use rate, respectively (Figure 5). Within the tandem disk category, 50% was done with a finishing disk while 28% used a cutting disk and 22% used a combination disk (Figure 6). Incorporation with a spring-mounted field cultivator accounted for 98% of the total (Figure 7). Of these, 83% were equipped with shovel sweeps, while 10% and 5% were equipped with forged points and chisel points, respectively. The remaining 52% of the incorporating devices were divided among flexible shank cultivators (6%), power-driven tillers (1%), spike/spring tooth harrows (13%), ground-driven devices (17%), or combination devices (15%).

Flexible shank cultivators accounted for 6% of the various types of incorporating devices. Seventy-five percent of these were a coiled S-tine type implement (Figure 8) equipped with either goosefoot sweeps (50% of total) or chisel sweeps (25% of total).

Spike or spring tooth harrows were used 13% of the time, with 75% of these being a spike tooth harrow (Figure 9). Ground-driven devices ranked third in use for incorporation. Of this, a rolling cultivator was used 68% of the time (Figure 10).

Conclusions

Historically, herbicide application techniques have been tailored to provide the most effective use of available compounds. Classic examples of this include: incorporation of dinitroaniline type herbicides, post-directed sprays of compounds such as diuron or fluometuron which were originally developed for preemergence use, and ropewick applications. Based on the results presented, this is still the case today. For example, the introduction of sethoxydim and fluazifop has aroused interest in spot applications because of costs and scattered, light infestations of problem grasses such as johnsongrass [*Sorghum halepense* (L.) Pers.].

The most obvious gap in herbicide application technology is the low prevalence of POT sprays. This is directly related to the lack of selective and effective postemergence broadleaf compounds and also explains the heavy dependence upon post-directed sprays. Also, the apparent need for cultivation because of widespread use of preemergence sprays applied as a band reinforces the need for postemergence sprays.

Acknowledgments

The authors gratefully acknowledge the time taken by Mississippi cotton producers and other respondents to complete the survey questionnaire on which this publication was based.

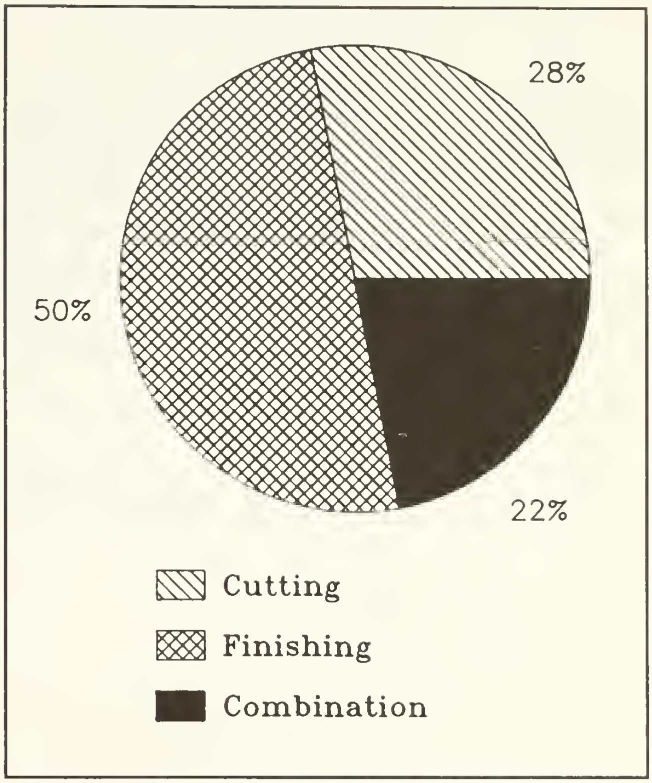


Figure 6. Producer preference of specific types of tandem disks for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.

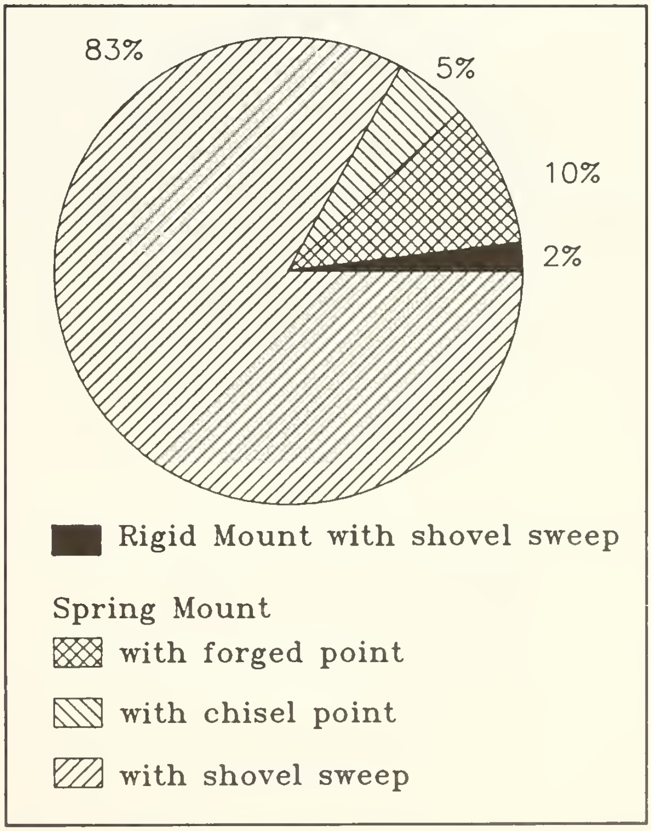


Figure 7. Producer preference of specific types of field cultivators used for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.

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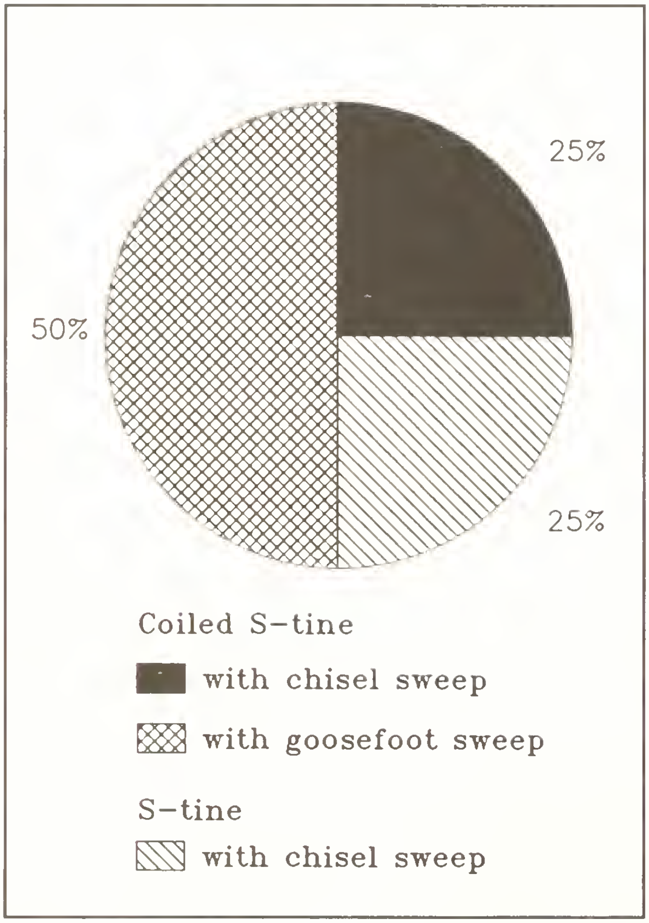

Figure 8. Producer preference of specific types of flexible shank cultivators used for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.

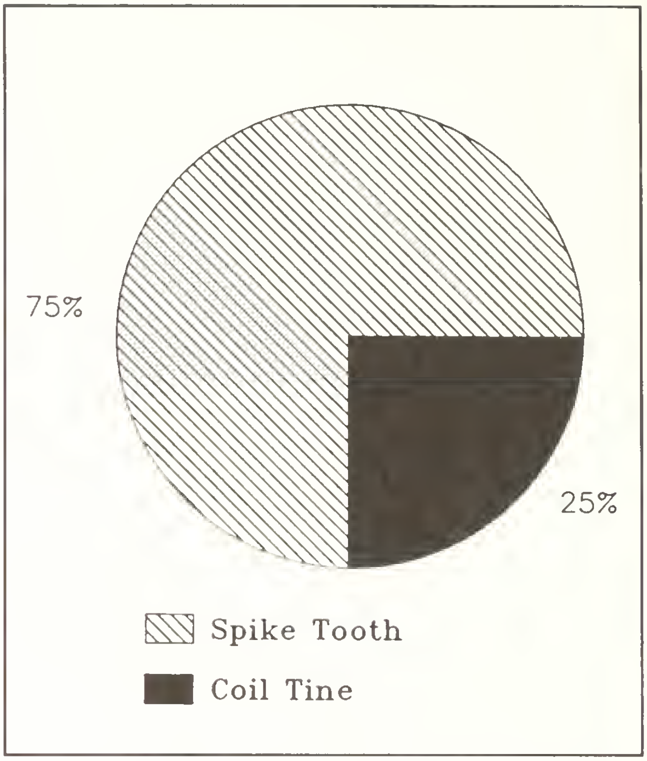

Figure 9. Producer preference of specific types of spike/spring tooth harrows used for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.

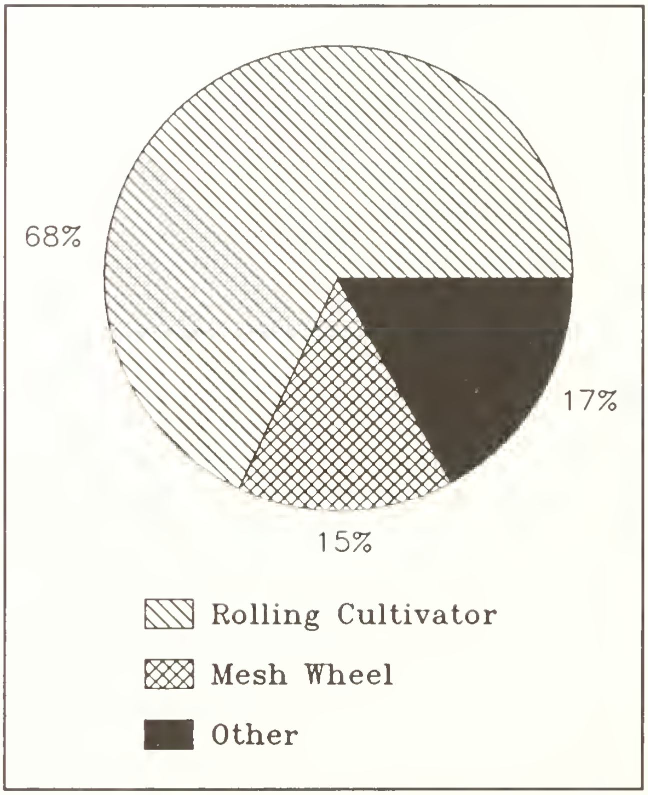

Figure 10. Producer preference of specific types of ground-driven devices used for incorporation of dinitroaniline-type herbicides in Mississippi cotton, 1987.

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1985-1988

Acreage Allocated to Conservation Tillage Practices in Mississippi

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Acreage Allocated to Conservation Tillage Practices in Mississippi, 1985-1988

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Acreage Allocated to Conservation Tillage Practices in Mississippi, 1985-1988

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Reducing soil erosion rates to acceptable levels has been, and continues to be, a major concern in the United States. Conservation tillage practices have the potential to reduce soil loss on much of the row crop acreage throughout the nation. Figure 1 presents estimates of percentage reductions in soil loss that can be expected by switching from conventional tillage to three types of conservation tillage for three row crops in Mississippi.

The percentage reductions in soil loss were calculated by using "C-values" for selected cropping management systems in Mississippi, which were developed by the Soil Conservation Service (SCS). A cropping management system includes a definition of pre-plant tillage operations, cultivation practices, and crop residue requirements. A long-run average annual C-value is calculated by the SCS for each cropping management system to reflect the soil erosion potential of the system (USDA-SCS). The more erosive the system, the greater the C-value. The Universal Soil Loss Equation can be used to estimate the long-run average annual erosion rate on a particular field once the C-value and other determinants are specified.

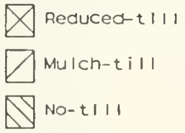
As shown in Figure 1, switching from conventional tillage to reduced tillage can potentially decrease soil erosion by about 50 percent. Mulch-till and no-till systems can reduce soil loss relative to conventional tillage by approximately 60 and 85 percent, respectively. Thus, depending on the crop, soil type, location, and other factors that influence the erosion rate, conservation tillage practices could possibly be used to attain acceptable erosion rates. However, the adoption of conservation tillage depends on many factors; the profitability of conservation tillage relative to conventional tillage is of primary importance.

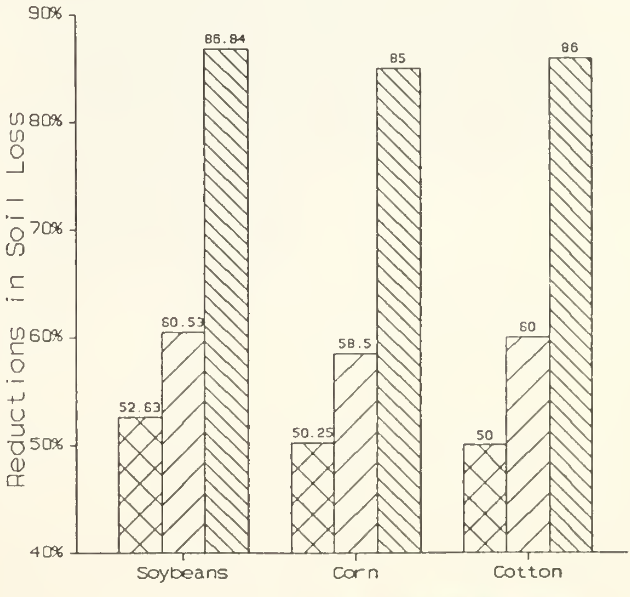
The Conservation Technology Information Center (CTIC) conducts a national survey annually to provide county-level data on the use of conservation tillage practices. Based on the percentage of total planted acres produced with conservation tillage practices in 1988, Mississippi ranked 36th among all states in the nation. Conservation tillage was used on only 19.54 percent of Mississippi's planted acreage. Even though conservation tillage practices can reduce soil erosion rates substantially, conventional tillage is still used on the majority of Mississippi cropland.

Other surrounding states, their 1988 national rankings, and their percentages of conservation tillage are: Tennessee, 22nd, 35.50 percent; Alabama, 37th, 19.34 percent; Arkansas, 40th, 13.48 percent; and Louisiana, 41st, 10.37 percent.

Farmers, landowners, policy makers, and research and extension personnel often require up-to-date information on conservation tillage practices. The pur-

Figure 1. Percentage soil loss reductions of three conservation tillage practices relative to conventional tillage for three Mississippi crops.





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pose of this study was to compile and present data on acreage allocated to different types of conservation tillage practices on major row crops in Mississippi during the period 1985-1988. The source was the CTIC, which collects data with help from local representatives of the Soil Conservation Service, the Cooperative Extension Service, Conservation Districts, the Agricultural Stabilization and Conservation Service, and others in agriculture-related fields.

Conservation tillage is defined by the CTIC as: *Any tillage and planting system that maintains at least 30 percent of the soil surface covered by residue after planting to reduce soil erosion by water; or where soil erosion by wind is the primary concern, maintains at least 1,000 pounds of flat small grain residue equivalent on the surface during the critical erosion period.*

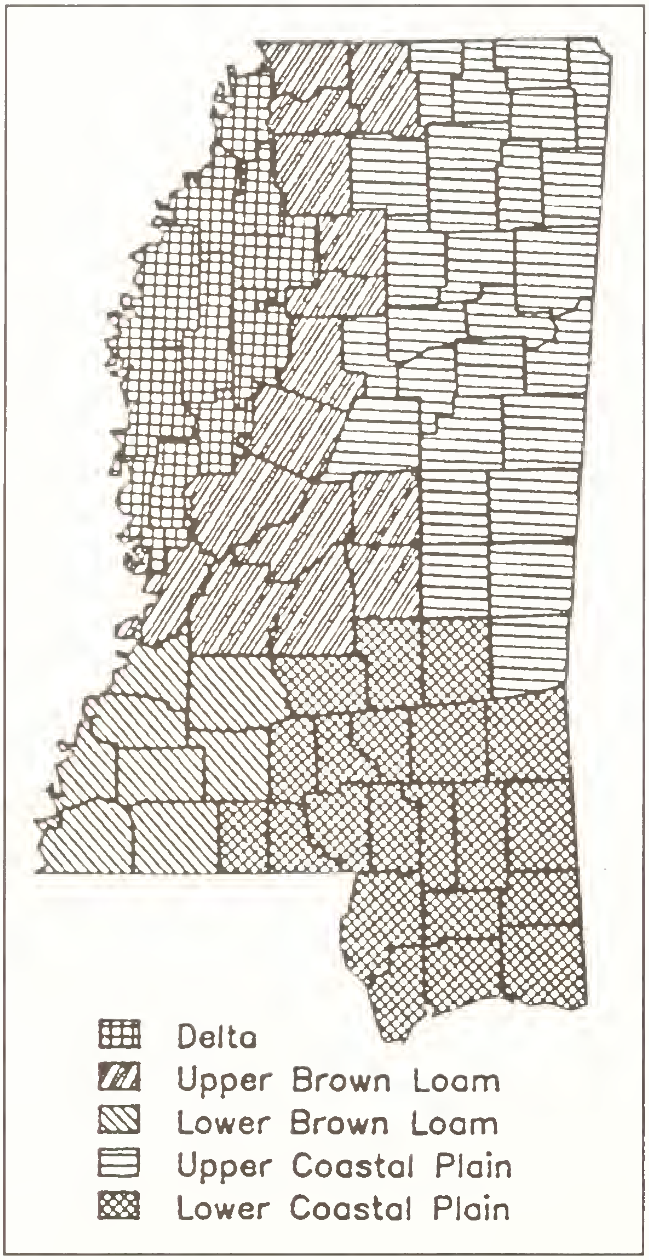

Figure 2. Counties comprising the five soil resource areas that were defined for Mississippi.

The CTIC also defines five specific conservation tillage practices, which are listed below.

No-till: The soil is left undisturbed prior to planting. Planting is completed in a narrow seedbed or slot created by a planter or drill. Weed control is accomplished primarily with herbicides.

Ridge-till: The soil is left undisturbed prior to planting. Planting is completed in a seedbed prepared in ridges with sweeps, discs, or other row cleaners. Residue is left on the surface between ridges. Weed control is accomplished with a combination of herbicides and/or cultivation. Ridges are rebuilt during cultivation.

Strip-till: The soil is left undisturbed prior to planting. Tillage in the row may consist of a rototiller, in-row chisel, row cleaners, etc. Weed control is accomplished with a combination of herbicides and/or cultivation.

Mulch-till: The total surface is disturbed by tillage prior to planting. Tillage tools such as chisels, field cultivators, discs, sweeps, or blades are used. Weed control is accomplished with a combination of herbicides and/or cultivation.

Reduced-till: Any other tillage and planting system not covered above that meets the residue requirement.

Methods and Procedures

Ten major soil resource areas in Mississippi have been identified (Pettry). These areas reflect groups of soils, as well as topographic and geological conditions, and thus are not based on county boundaries. To utilize the county-level data provided by the CTIC, county boundaries were used to group the 10 major soil resource areas into five soil resource areas. Only five soil resource areas were defined to ensure an adequate number of counties in each area (Figure 2). The names of the newly defined areas, with their usual soil resource area names in parentheses, are: Delta (Delta), Upper Brown Loam (Upper Thick Loess and Upper Thin Loess), Lower Brown Loam (Lower Thick Loess and Lower Thin Loess), Upper Coastal Plain (Upper Coastal Plain, Interior Flatwoods, and Blackland Prairie), and Lower Coastal Plain (Lower Coastal Plain and Coastal Flatwoods).

Primary row crops in the study are: monocrop and doublecrop soybeans, corn, grain sorghum, and cotton. Total planted acres and acres allocated to the five types of conservation tillage practices for each crop in each county were summed to obtain acreage values for each soil resource area. It was found that ridge-till and strip-till were not used at all, or were used in very small amounts. Thus, only acreage data for no-till, mulch-till, and reduced-till are presented in this paper.

Tables were developed for each soil resource area to show annual (1985-1988) and 4-year averages of total planted acreage, acreage allocated to the remaining three types of conservation tillage practices, and the percentage of the total planted acreage of each type of conservation tillage practice. Also, no-till, mulch-till, and reduced-till acres were summed to obtain total acres of conservation tillage. Finally, the 4-year averages for each crop in each soil resource area were summarized in two tables to facilitate comparison of conservation tillage practices across the state.

Delta Area

Data for the Delta area are presented in Table 1. Monocrop soybeans and cotton utilize a major portion of the row crop acreage in this area of the state. Corn is a minor crop in this area and was not listed. Cotton production does not exhibit much use of conservation tillage. Monocrop soybeans and grain sorghum utilize, in order of importance, reduced-till, mulch-till, and no-till. The production of doublecrop soybeans exhibits reduced-till, no-till, and mulch-till in order of importance and also has much higher percentages of conservation tillage than the monocrops.

Upper Brown Loam

Table 2 presents data for the Upper Brown Loam area. A major portion of the row crop acreage in this area consists of monocrop soybeans and cotton. Corn has the lowest acreage among the monocrops. Cotton exhibits minor use of conservation tillage. Monocrop soybeans and grain sorghum exhibit reduced-till, mulch-till, and no-till, in order of importance, while corn uses almost equal amounts of mulch-till and reduced-till. Almost equal amounts of no-till and mulch-till are used to produce doublecrop soybeans. Also, more conservation tillage is utilized on doublecrop soybeans than on the monocrops.

Lower Brown Loam

Data for the Lower Brown Loam area appear in Table 3. The major row crop in this area is monocrop soybeans. Grain sorghum and doublecrop soybeans show a declining trend in acreage. Cotton exhibits virtually no use of conservation tillage. Slightly more reduced-till than either mulch-till or no-till is used on

Table 1. Acres and percentages of conservation tillage practices for selected crops, Delta area of Mississippi, 1985-88.

	Planted	No-till		Mulch-till		Reduced-till		Total Cons.-till*	
	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(%)	(acres)	(%)
Monocrop Soybeans									
1985	1,260,712	7,640	0.6	20,090	1.6	89,300	7.1	117,030	9.3
1986	1,261,529	26,720	2.1	33,920	2.7	164,900	13.1	225,540	17.9
1987	1,001,684	6,900	0.7	18,664	1.9	30,478	3.0	56,042	5.6
1988	988,909	21,945	2.2	38,000	3.8	72,000	7.3	131,945	13.3
Avg.	1,128,209	15,801	1.4	27,669	2.5	89,170	7.9	132,639	11.8
Doublecrop Soybeans									
1985	56,724	8,130	14.3	5,200	9.2	13,850	24.4	27,180	47.9
1986	56,091	5,800	10.3	2,000	3.6	12,500	22.3	20,300	36.2
1987	117,950	12,000	10.2	8,850	7.5	19,800	16.8	40,650	34.5
1988	129,917	18,600	14.3	14,800	11.4	42,500	32.7	75,900	58.4
Avg.	90,171	11,133	12.3	7,713	8.6	22,163	24.6	41,008	45.5
Grain Sorghum									
1985	196,944	2,542	1.3	4,250	2.2	20,860	10.6	27,652	14.0
1986	166,864	1,340	0.8	4,980	3.0	16,600	9.9	22,920	13.7
1987	72,792	2,500	3.4	5,500	7.6	7,000	9.6	15,000	20.6
1988	57,466	3,700	6.4	13,500	23.5	6,600	11.5	23,800	41.4
Avg.	123,517	2,521	2.0	7,058	5.7	12,765	10.3	22,343	18.1
Cotton									
1985	556,348	680	0.1	5,000	0.9	0	0.0	5,680	1.0
1986	577,857	65	0.0	3,000	0.5	26,750	4.6	29,815	5.2
1987	556,861	120	0.0	3,693	0.7	6,100	1.1	9,913	1.8
1988	654,700	0	0.0	4,800	0.7	15,500	2.4	20,300	3.1
Avg.	586,442	216	0.0	4,123	0.7	12,088	2.1	16,427	2.8

*The sum of no-till, mulch-till, and reduced-till.

Source: County-level data provided by the Conservation Technology Information Center.

monocrop soybeans. No-till is employed more often than the other types of conservation tillage in corn production. Grain sorghum exhibits almost equal amounts of mulch-till and reduced-till, and very little no-till. Almost equal amounts of no-till and reduced-till are used in the production of doublecrop soybeans.

Upper Coastal Plain

Data in Table 4 describe tillage practices in the Upper Coastal Plain area, where more land is devoted to monocrop soybeans than any other row crop. Both types of soybeans and grain sorghum exhibit a declining trend in acreage. Cotton uses little conservation tillage, but monocrop soybeans and grain sorghum use reduced-till, mulch-till, and no-till in order of importance. Corn and doublecrop soybeans use, in order of importance, reduced-till, no-till, and mulch-till.

Lower Coastal Plain

Data for the Lower Coastal Plain area are presented in Table 5, where the largest portion of the row crop acreage is devoted to monocrop soybeans. Cotton is a minor crop and was not listed. Grain sorghum and corn exhibit a declining trend in acreage. Mulch-till is the predominant conservation tillage practice among all monocrops, followed by reduced-till and no-till. Almost equal amounts of the three types of conservation tillage practices are used to produce doublecrop soybeans.

Summary of Practices

Table 6 displays the 4-year averages for each crop grouped by soil resource areas. The Delta area, which has the lowest erosion rates in the state, uses relatively less conservation tillage (11.0 percent) than the

Table 2. Acres and percentages of conservation tillage practices for selected crops, Upper Brown Loam area of Mississippi, 1985-88.

	Planted	No-till		Mulch-till		Reduced-till		Total Cons.-till*	
	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(%)	(acres)	(%)
Monocrop Soybeans									
1985	480,265	3,498	0.7	27,185	5.7	39,186	8.2	69,869	14.5
1986	435,864	6,385	1.5	53,979	12.4	51,200	11.7	111,564	25.6
1987	330,372	3,992	1.2	18,200	5.5	14,000	4.2	36,192	11.0
1988	339,385	2,925	0.9	19,300	5.7	52,850	15.6	75,075	22.1
Avg.	396,472	4,200	1.1	29,666	7.5	39,309	9.9	73,175	18.5
Doublecrop Soybeans									
1985	36,891	5,815	15.8	5,700	15.5	3,280	8.9	14,795	40.1
1986	34,273	1,635	4.8	11,440	33.4	3,800	11.1	16,875	49.2
1987	48,430	11,221	23.2	8,715	18.0	3,850	7.9	23,786	49.1
1988	39,901	10,876	27.3	6,750	16.9	6,452	16.2	24,078	60.3
Avg.	39,874	7,387	18.5	8,151	20.4	4,346	10.9	19,884	49.9
Corn									
1985	42,624	861	2.0	2,706	6.3	2,741	6.4	6,308	14.8
1986	52,304	1,532	2.9	8,193	15.7	8,925	17.1	18,650	35.7
1987	40,416	2,074	5.1	7,150	17.7	2,650	6.6	11,874	29.4
1988	41,724	2,053	4.9	2,940	7.0	4,280	10.3	9,273	22.2
Avg.	44,267	1,630	3.7	5,247	11.9	4,649	10.5	11,526	26.0
Grain Sorghum									
1985	138,219	1,085	0.8	4,700	3.4	17,397	12.6	23,182	16.8
1986	108,670	892	0.8	7,475	6.9	13,161	12.1	21,528	19.8
1987	33,894	1,918	5.7	3,383	10.0	1,395	4.1	6,696	19.8
1988	45,512	0	0.0	1,150	2.5	2,990	6.6	4,140	9.1
Avg.	81,574	974	1.2	4,177	5.1	8,736	10.7	13,887	17.0
Cotton									
1985	335,361	17	0.0	2,476	0.7	25,513	7.6	28,006	8.4
1986	306,134	40	0.0	750	0.2	4,600	1.5	5,390	1.8
1987	313,863	115	0.0	768	0.2	0	0.0	883	0.3
1988	363,353	238	0.1	0	0.0	4,602	1.3	4,840	1.3
Avg.	329,678	103	0.0	999	0.3	8,679	2.6	9,780	3.0

*The sum of no-till, mulch-till, and reduced-till.

Source: County-level data provided by the Conservation Technology Information Center.

other areas. The Coastal Plain areas use more conservation tillage than the Brown Loam areas, which have the highest erosion rates among all areas in Mississippi. More use of conservation tillage practices in the Brown Loam areas would lead to significant reductions in soil erosion.

The 4-year averages for each soil resource area grouped by crops are presented in Table 7. Very little conservation tillage (2.6 percent) is used on cotton, while a high proportion of conservation tillage (41.2 percent) is used on doublecrop soybeans. The percentage of no-till is very low for all monocrops in all areas, with the exception of corn in the Lower Brown Loam and Upper Coastal Plain areas. However, no-till is used quite often (from 9.1 to 18.5 percent of planted acreage) on doublecrop soybeans. Based on total acreage data for each crop, reduced-till is more prevalent than mulch-till. However, crops in some areas use more mulch-till than reduced-till.

The percentage of conservation tillage that is used for a given crop in a given area is partly a function of the profitability of conservation tillage versus conventional tillage. Thus, based on information provided in Tables 6 and 7, it appears that conservation tillage for cotton is not very profitable in Mississippi.

Conservation tillage is used on about 16 and 41 percent, respectively, of the monocrop soybean and doublecrop soybean acreage. If the apparent profitability of conservation tillage on doublecrop soybeans could be transferred to monocrop soybeans, then significant reductions in erosion could be obtained throughout the state. About one-fourth and one-fifth of the state's corn and grain sorghum acreage, respectively, use conservation tillage. Increases in the use

Table 3. Acres and percentages of conservation tillage practices for selected crops, Lower Brown Loam area of Mississippi, 1985-88.

	Planted	No-till		Mulch-till		Reduced-till		Total Cons.-till*	
	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(%)	(acres)	(%)
Monocrop Soybeans									
1985	76,732	6,405	8.3	9,324	12.2	6,844	8.9	22,573	29.4
1986	66,700	2,375	3.6	2,000	3.0	9,800	14.7	14,175	21.3
1987	53,525	1,200	2.2	0	0.0	2,000	3.7	3,200	6.0
1988	57,950	170	0.3	800	1.4	100	0.2	1,070	1.8
Avg.	63,727	2,538	4.0	3,031	4.8	4,686	7.4	10,255	16.1
Doublecrop Soybeans									
1985	15,184	700	4.6	1,250	8.2	1,000	6.6	2,950	19.4
1986	10,655	2,118	19.9	450	4.2	2,532	23.8	5,100	47.9
1987	7,522	600	8.0	0	0.0	0	0.0	600	8.0
1988	4,350	800	18.4	400	9.2	500	11.5	1,700	39.1
Avg.	9,428	1,055	11.2	525	5.6	1,008	10.7	2,588	27.4
Corn									
1985	24,265	3,590	14.8	754	3.1	0	0.0	4,344	17.9
1986	29,950	2,120	7.1	2,100	7.0	1,000	3.3	5,220	17.4
1987	20,395	1,605	7.9	0	0.0	0	0.0	1,605	7.9
1988	17,650	2,425	13.7	250	1.4	500	2.8	3,175	18.0
Avg.	23,065	2,435	10.6	776	3.4	375	1.6	3,586	15.5
Grain Sorghum									
1985	15,800	400	2.5	2,225	14.1	714	4.5	3,339	21.1
1986	11,850	0	0.0	0	0.0	1,500	12.7	1,500	12.7
1987	3,225	0	0.0	0	0.0	0	0.0	0	0.0
1988	1,080	0	0.0	140	13.0	200	18.5	340	31.5
Avg.	7,989	100	1.3	591	7.4	604	7.6	1,295	16.2
Cotton									
1985	7,009	0	9.0	235	3.4	90	1.3	325	4.6
1986	5,078	0	0.0	0	0.0	0	0.0	0	0.0
1987	7,224	0	0.0	0	0.0	0	0.0	0	0.0
1988	9,169	0	0.0	0	0.0	0	0.0	0	0.0
Avg.	7,120	0	0.0	59	0.8	23	0.3	81	1.1

*The sum of no-till, mulch-till, and reduced-till.

Source: County-level data provided by the Conservation Technology Information Center.

of conservation tillage on these crops could also result in reductions in soil loss.

More research is needed to develop more profitable conservation tillage practices for the row crops produced in Mississippi. The agronomic and economic impacts of alternative cropping management systems need to be evaluated for the various soil types found across the state. It is possible that more educational efforts are needed to promote those types of conservation tillage practices that will not only benefit farmers financially, but also will reduce erosion rates to acceptable levels.

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Table 4. Acres and percentages of conservation tillage practices for selected crops, Upper Coastal Plain area of Mississippi, 1985-88.

	Planted	No-till		Mulch-till		Reduced-till		Total Cons.-till*	
	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(%)	(acres)	(%)
Monocrop Soybeans									
1985	708,377	6,325	0.9	13,875	2.0	94,738	13.4	114,938	16.2
1986	692,764	15,805	2.3	70,870	10.2	47,275	6.8	133,950	19.3
1987	550,058	5,116	0.9	7,200	1.3	77,950	14.2	90,266	16.4
1988	536,987	4,250	0.8	17,600	3.3	132,105	24.6	153,955	28.7
Avg.	622,047	7,874	1.3	27,386	4.4	88,017	14.1	123,277	19.8
Doublecrop Soybeans									
1985	63,956	7,335	11.5	1,300	2.0	13,170	20.6	21,805	34.1
1986	85,772	3,573	4.2	1,043	1.2	31,000	36.1	35,616	41.5
1987	40,474	5,624	13.9	1,100	2.7	6,200	15.3	12,924	31.9
1988	45,790	10,540	23.0	1,600	3.5	9,680	21.1	21,820	47.7
Avg.	58,998	6,768	11.5	1,261	2.1	15,013	25.4	23,041	39.1
Corn									
1985	75,753	6,890	9.1	4,045	5.3	5,095	6.7	16,030	21.2
1986	92,852	6,095	6.6	4,825	5.2	11,085	11.9	22,005	23.7
1987	88,592	6,095	6.9	2,170	2.4	20,720	23.4	28,985	32.7
1988	86,643	6,945	8.0	3,870	4.5	29,050	33.5	39,865	46.0
Avg.	85,960	6,506	7.6	3,728	4.3	16,488	19.2	26,721	31.1
Grain Sorghum									
1985	185,724	2,566	1.4	5,053	2.7	31,722	17.1	39,341	21.2
1986	165,599	2,420	1.5	20,850	12.6	17,570	10.6	40,840	24.7
1987	60,862	1,180	1.9	600	1.0	13,606	22.4	15,386	25.3
1988	40,497	602	1.5	2,425	6.0	8,450	20.9	11,477	28.3
Avg.	113,171	1,692	1.5	7,232	6.4	17,837	15.8	26,761	23.6
Cotton									
1985	109,191	50	0.0	157	0.1	150	0.1	357	0.3
1986	128,122	65	0.1	0	0.0	2,200	1.7	2,265	1.8
1987	135,801	208	0.2	75	0.1	500	0.4	783	0.6
1988	156,895	317	0.2	200	0.1	2,675	1.7	3,192	2.0
Avg.	132,502	160	0.1	108	0.1	1,381	1.0	1,649	1.2

*The sum of no-till, mulch-till, and reduced-till.

Source: County-level data provided by the Conservation Technology Information Center.

Table 5. Acres and percentages of conservation tillage practices for selected crops, Lower Coastal Plain area of Mississippi, 1985-88.

	Planted	No-till		Mulch-till		Reduced-till		Total Cons.-till*	
	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(%)	(acres)	(%)
Monocrop Soybeans									
1985	99,406	5,221	5.3	8,400	8.5	12,990	13.1	26,611	26.8
1986	92,025	3,720	4.0	16,800	18.3	10,007	10.9	30,527	33.2
1987	47,428	800	1.7	7,361	15.5	553	1.2	8,714	18.4
1988	66,713	793	1.2	15,475	23.2	11,925	17.9	28,193	42.3
Avg.	76,393	2,634	3.4	12,009	15.7	8,869	11.6	23,511	30.8
Doublecrop Soybeans									
1985	59,527	10,305	17.3	5,340	9.0	5,628	9.5	21,273	35.7
1986	37,260	1,316	3.5	1,100	3.0	7,000	18.8	9,416	25.3
1987	36,783	2,355	6.4	5,778	15.7	600	1.6	8,733	23.7
1988	37,590	1,680	4.5	7,850	20.9	2,178	5.8	11,708	31.1
Avg.	42,790	3,914	9.1	5,017	11.7	3,852	9.0	12,783	29.9
Corn									
1985	61,275	2,280	3.7	4,530	7.4	6,362	10.4	13,172	21.5
1986	56,146	1,340	2.4	11,737	20.9	4,655	8.3	17,732	31.6
1987	39,630	1,550	3.9	2,268	5.7	1,492	3.8	5,310	13.4
1988	38,961	1,295	3.3	5,706	14.6	7,919	20.3	14,920	38.3
Avg.	49,003	1,616	3.3	6,060	12.4	5,107	10.4	12,784	26.1
Grain Sorghum									
1985	20,178	125	0.6	2,595	12.9	1,790	8.9	4,510	22.4
1986	17,788	450	2.5	2,880	16.2	1,896	10.7	5,226	29.4
1987	8,981	100	1.1	450	5.0	14	0.2	564	6.3
1988	7,260	0	0.0	1,100	15.2	300	4.1	1,400	19.3
Avg.	13,552	169	1.2	1,756	13.0	1,000	7.4	2,925	21.6

*The sum of no-till, mulch-till, and reduced-till.

Source: County-level data provided by the Conservation Technology Information Center.

Table 6. Acres and percentages of conservation tillage practices for crops grouped by five soil resource areas of Mississippi, 4-year (1985-1988) averages.

	Planted	No-till		Mulch-till		Reduced-till		Total Cons.-till*	
	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(%)	(acres)	(%)
Delta									
MCS	1,128,209	15,801	1.4	27,669	2.5	89,170	7.9	132,639	11.8
DCS	90,171	11,133	12.3	7,713	8.6	22,163	24.6	41,008	45.5
GS	123,517	2,521	2.0	7,058	5.7	12,765	10.3	22,343	18.1
Ct	586,442	216	0.0	4,123	0.7	12,088	2.1	16,427	2.8
Total	1,928,337	29,671	1.5	46,562	2.4	136,185	7.1	212,417	11.0
Upper Brown Loam									
MCS	396,472	4,200	1.1	29,666	7.5	39,309	9.9	73,175	18.5
DCS	39,874	7,387	18.5	8,151	20.4	4,346	10.9	19,884	49.9
Cn	44,267	1,630	3.7	5,247	11.9	4,649	10.5	11,526	26.0
GS	81,574	974	1.2	4,177	5.1	8,736	10.7	13,887	17.0
Ct	329,678	103	0.0	999	0.3	8,679	2.6	9,780	3.0
Total	891,864	14,293	1.6	48,240	5.4	65,718	7.4	128,251	14.4
Lower Brown Loam									
MCS	63,727	2,538	4.0	3,031	4.8	4,686	7.4	10,255	16.1
DCS	9,428	1,055	11.2	525	5.6	1,008	10.7	2,588	27.4
Cn	23,065	2,435	10.6	776	3.4	375	1.6	3,586	15.5
GS	7,989	100	1.3	591	7.4	604	7.6	1,295	16.2
Ct	7,120	0	0.0	59	0.8	23	0.3	81	1.1
Total	111,328	6,127	5.5	4,982	4.5	6,695	6.0	17,804	16.0
Upper Coastal Plain									
MCS	622,047	7,874	1.3	27,386	4.4	88,017	14.1	123,277	19.8
DCS	58,998	6,768	11.5	1,261	2.1	15,013	25.4	23,041	39.1
Cn	85,960	6,506	7.6	3,728	4.3	16,488	19.2	26,721	31.1
GS	113,171	1,692	1.5	7,232	6.4	17,837	15.8	26,761	23.6
Ct	132,502	160	0.1	108	0.1	1,381	1.0	1,649	1.2
Total	1,012,677	23,000	2.3	39,715	3.9	138,735	13.7	201,450	19.9
Lower Coastal Plain									
MCS	76,393	2,634	3.4	12,009	15.7	8,869	11.6	23,511	30.8
DCS	42,790	3,914	9.1	5,017	11.7	3,852	9.0	12,783	29.9
Cn	49,003	1,616	3.3	6,060	12.4	5,107	10.4	12,784	26.1
GS	13,552	169	1.2	1,756	13.0	1,000	7.4	2,925	21.6
Total	181,738	8,333	4.6	24,843	13.7	18,827	10.4	52,002	28.6
State Total	4,125,944	81,423	2.0	164,341	4.0	366,160	8.9	611,924	14.8

*The sum of no-till, mulch-till, and reduced-till.

Note: MCS – Monocrop Soybeans; DCS – Doublecrop Soybeans; Cn – Corn;
GS – Grain Sorghum; Ct – Cotton;
Total – Sum of all crops for each area; State Total – Sum of all totals.

Source: County-level data provided by the Conservation Technology Information Center.

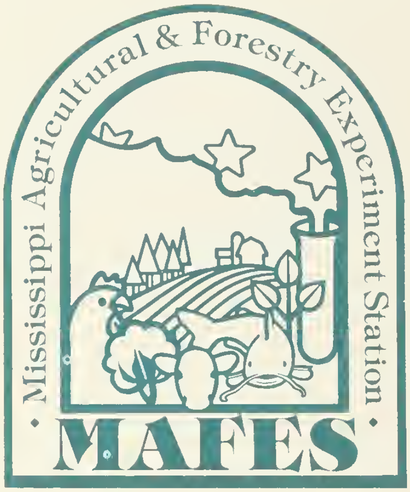
Table 7. Acres and percentages of conservation tillage practices for five soil resource areas of Mississippi grouped by crops, 4-year (1985-1988) averages.

	Planted	No-till		Mulch-till		Reduced-till		Total Cons.-till*	
	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(%)	(acres)	(%)
Monocrop Soybeans									
D	1,128,209	15,801	1.4	27,669	2.5	89,170	7.9	132,639	11.8
UBL	396,472	4,200	1.1	29,666	7.5	39,309	9.9	73,175	18.5
LBL	63,727	2,538	4.0	3,031	4.8	4,686	7.4	10,255	16.1
UCP	622,047	7,874	1.3	27,386	4.4	88,017	14.1	123,277	19.8
LCP	76,393	2,634	3.4	12,009	15.7	8,869	11.6	23,511	30.8
Total	2,286,846	33,046	1.4	99,761	4.4	230,050	10.1	362,857	15.9
Doublecrop Soybeans									
D	90,171	11,133	12.3	7,713	8.6	22,163	24.6	41,008	45.5
UBL	39,874	7,387	18.5	8,151	20.4	4,346	10.9	19,884	49.9
LBL	9,428	1,055	11.2	525	5.6	1,008	10.7	2,588	27.4
UCP	58,998	6,768	11.5	1,261	2.1	15,013	25.4	23,041	39.1
LCP	42,790	3,914	9.1	5,017	11.7	3,852	9.0	12,783	29.9
Total	241,260	30,256	12.5	22,667	9.4	46,380	19.2	99,302	41.2
Corn									
UBL	44,267	1,630	3.7	5,247	11.9	4,649	10.5	11,526	26.0
LBL	23,065	2,435	10.6	776	3.4	375	1.6	3,586	15.5
UCP	85,960	6,506	7.6	3,728	4.3	16,488	19.2	26,721	31.1
LCP	49,003	1,616	3.3	6,060	12.4	5,107	10.4	12,784	26.1
Total	202,295	12,188	6.0	15,811	7.8	26,619	13.2	54,617	27.0
Grain Sorghum									
D	123,517	2,521	2.0	7,058	5.7	12,765	10.3	22,343	18.1
UBL	81,574	974	1.2	4,177	5.1	8,736	10.7	13,887	17.0
LBL	7,989	100	1.3	591	7.4	604	7.6	1,295	16.2
UCP	113,171	1,692	1.5	7,232	6.4	17,837	15.8	26,761	23.6
LCP	13,552	169	1.2	1,756	13.0	1,000	7.4	2,925	21.6
Total	339,801	5,455	1.6	20,814	6.1	40,941	12.0	67,210	19.8
Cotton									
D	586,442	216	0.0	4,123	0.7	12,088	2.1	16,427	2.8
UBL	329,678	103	0.0	999	0.3	8,679	2.6	9,780	3.0
LBL	7,120	0	0.0	59	0.8	23	0.3	81	1.1
UCP	132,502	160	0.1	108	0.1	1,381	1.0	1,649	1.2
Total	1,055,741	479	0.0	5,289	0.5	22,170	2.1	27,937	2.6
State Total	4,125,944	81,423	2.0	164,341	4.0	366,160	8.9	611,924	14.8

*The sum of no-till, mulch-till, and reduced-till.

Note: D – Delta; UBL – Upper Brown Loam; LBL – Lower Brown Loam;
UCP – Upper Coastal Plain; LCP – Lower Coastal Plain;
Total – Sum of all areas for each crop; State Total – Sum of all totals.

Source: County-level data provided by the Conservation Technology Information Center.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1983-1987 (II)

The Influence of Winter Vegetation on Seedbed Preparation and Weed Control in COTTON

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The Influence of Winter Vegetation on Seedbed Preparation and Weed Control in Cotton – (II) 1983-1987

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Plant Physiologist
Delta Branch Experiment Station

spray shields and two nozzles per row. Over-the-top (OT) treatments (1984-86) were applied broadcast as described above.

General postemergence herbicides and broadcast rates used in these studies (see Table 1 for dates of application) were Cotoran at 1.5 lb/acre plus surfactant at 0.25% v/v (DIR) in 1983; Cotoran at 1.5 lb/acre plus surfactant at 0.25% v/v (OT), Poast® (sethoxydim) to treatment 1 only at 0.3 lb a.i./acre plus surfactant at 0.5% v/v (OT), and Cobra® (lactofen) at 0.2 lb a.i./acre plus surfactant at 0.25% v/v (DIR) in 1984; Verdict® (haloxyfop) at 0.0625 lb a.i./acre plus crop oil concentrate at 1.25% v/v (OT) in 1985; Poast at 0.2 lb/acre plus crop oil concentrate at 1.25% v/v (OT), Bladex® (cyanazine) at 0.6 lba.i./acre plus MSMA at 2.0 lb a.i./acre (DIR) in 1986; and Cotton-Pro® (prometryn) at 0.5 lb a.i./acre plus surfactant at 0.25% v/v (DIR) in 1987.

Estimates of the winter vegetation population were made in February or March 1983-86, and in November 1986, by counting individual plants by species on randomly placed 1 x 3-foot metal frames within each main plot. Counts were combined and are reported as plants per 15 square feet. All vegetative plant material above the soil line in randomly selected areas (each 1 by 3 feet) was removed by hand in March or April of each year to estimate the amount of plant residue for each cover crop area. These samples were dried to a constant weight in a forced air drier at 120°F, and the dry weight per acre was calculated.

Beds were formed with a conventional four-row disk hipper on the indicated dates (Table 1). The experiment was drill planted to 'DES 119' or 'DES 422' cotton with a John Deere 7100® four-row planter. All row middles were cultivated on the dates indicated with a two- or four-row cultivator equipped with spray shields positioned 6 inches from each side of the row. Cotton stand was determined by counting plants from one row in each plot. Plants per acre were calculated from these counts. Evaluation of summer weed control was made by counting weed plants by species and by determining the hoe time required to remove summer weeds (1984 and 1985 only). Weed counts were made 2 or 3 weeks after cotton emergence on randomly selected areas of 1 by 3 feet centered on row two of each subplot. These counts were combined and are reported as plants per 15 square feet. The time required to hoe the two center rows of each plot in 1984 and 1985 was determined 7-8 weeks after cotton emergence and is reported as hours per acre.

Cotton yield was determined by harvesting the two center rows of each plot with a one-row spindle picker adapted to harvest small plots. Plot yields were converted to pounds of seed cotton per acre.

An analysis of variance for a split plot design was used. Means were separated using Duncan's Multiple Range Test. The 5% confidence level was used.

Results and Discussion

Winter vegetation

The 1982-83 wheat stand was very poor (Table 2). However, the total dry weight harvested in April 1983

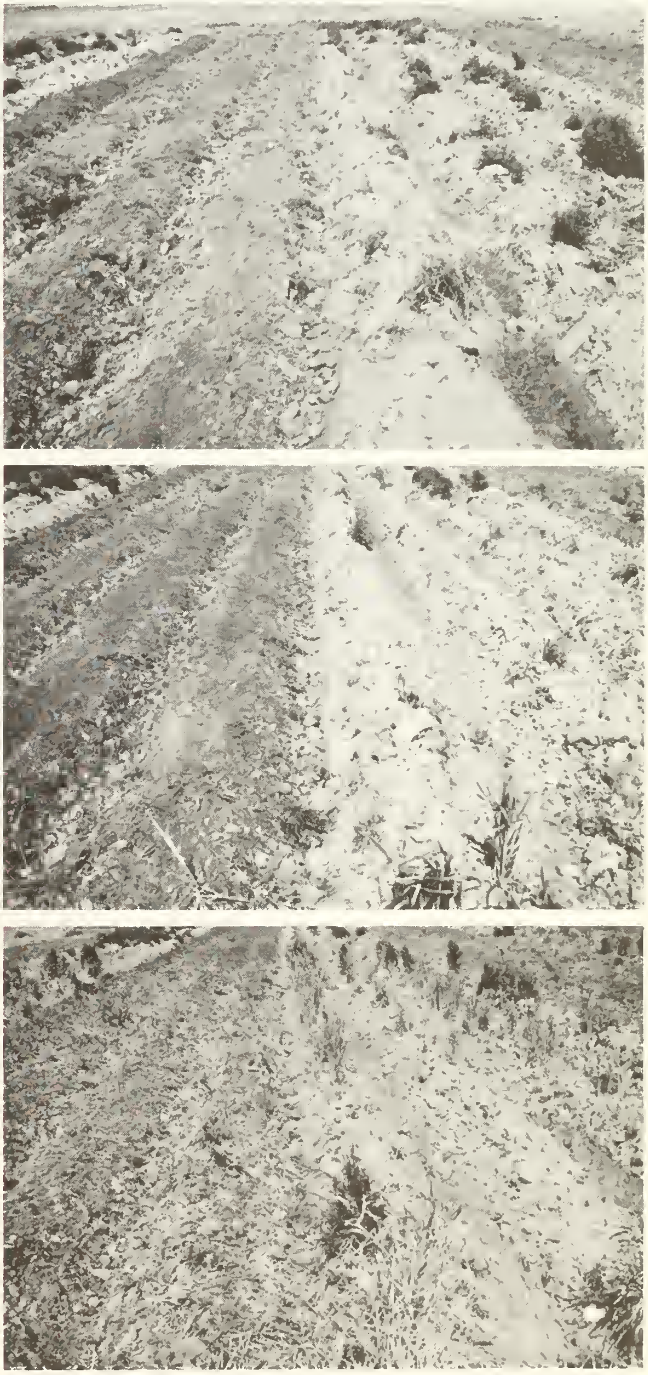

Figure 2. Field condition 5 days before planting in 1983 in the vetch area (top), winter weeds area (center) and wheat area (bottom). The left four rows in each photo were given a once-over treatment with a row conditioner one day before Treflan application.

was an acceptable yield compared to yields from most years in this study. The 1983-84 vetch stand was almost completely winterkilled due to an extremely cold December 1983 and resulted in a very low yield. The record low temperature in December 1983 adversely affected the winter growth of both vetch and weeds.

Winter weeds encountered in this study were: Annual bluegrass–*Poa annua* L.; Common chickweed–*Stellaria media* (L.) Vill; Corn speedwell–*Veronica arvensis* L.; Cutleaf eveningprimrose–*Oenothera laciniata* Hill; Hairy bittercress–*Cardamine hirsuta* L.; Henbit–*Lamium amplexicaule* L.; Mouseear chickweed–*Cerastium vulgatum* L.; Mousetail–*Myosurus minimus* L.; and Water foxtail–*Alopecurus geniculatus* L.

There were about as many winter weeds in 1984 as in 1983 (Table 2). The total numbers of winter weeds in all cover crop areas were 574.3 and 514.4 plants per 15 square feet for 1983 and 1984, respectively (Table 2). The low temperature probably suppressed plant growth severely enough to prevent an abundance of early growth in the spring of 1984.

The extreme low numbers of winter weeds in 1985 and in February 1986 indicate that germination and emergence were adversely affected by the cold, wet conditions in 1984-85 and the very wet fall of 1985. The dry weight yield in April 1985 reflected this very low number of winter weeds (total of 60.7 plants per 15 square feet). However, the dry weight yield in March 1986 reflected a greater number of winter weeds such as those that occurred in 1983. This yield

Table 2. Effect of winter cover crops and production operations on the composition and yield of winter vegetation on plots used to grow cotton with the production operations presented in Table 1. MAFES Delta Branch, 1983-87.

		Winter Vegetation										
		Plants per 15 square feet					Total dry weight when harvested on[1]					
		1983	1984	1985	1986		1983	1984	1985	1986	1987	
Cover Crop	Weed Species	Feb.	Mar.	Mar.	Feb.	Nov.	4/12	3/29	4/10	3/4	3/11	4/8
		(no.)					(tons/acre)					
Wheat		3.1	62.1	[3]	284.9	293.4	1.74	0.04 a	0.81 a	1.44 b	3.40	3.36 b
	Annual bluegrass	21.5	–	1.9	2.6	6.5						
	Common chickweed	23.9	3.1	–	6.0	18.9						
	Corn speedwell	5.8	2.3	2.3	0.3	0.9						
	Cutleaf eveningprimrose	6.4	–	–	2.3	–						
	Hairy bittercress	29.3	31.0	4.8	8.8	58.2						
	Henbit	41.3	56.6	0.9	17.1	245.3						
	Mouseear chickweed	–	–	–	2.9	7.5						
	Mousetail	–	20.0	0.6	–	9.2						
	Water foxtail	56.1	14.8	5.7	22.6	10.2						
Vetch		86.0	0.6[2]	[3]	437.0	297.8	1.56	0.03 ab	0.78 a	2.38 a	4.31	5.38 a
	Annual bluegrass	24.3	–	1.8	0.5	8.7						
	Common chickweed	57.3	6.3	–	1.7	20.9						
	Corn speedwell	9.3	5.0	0.7	–	1.5						
	Cutleaf eveningprimrose	5.9	–	–	0.1	–						
	Hairy bittercress	32.0	71.9	3.4	2.7	30.9						
	Henbit	41.0	84.4	0.5	13.5	294.5						
	Mouseear chickweed	–	–	–	0.6	8.0						
	Mousetail	–	13.5	2.0	–	6.5						
	Water foxtail	30.9	42.9	1.7	4.4	9.0						
Winter Weeds Only		–	–	–	–	–	1.37	0.01 b	0.28 b	1.29 b	4.00	4.37 ab
	Annual bluegrass	23.1	–	6.4	0.3	8.7						
	Common chickweed	38.3	5.6	2.0	6.8	20.1						
	Corn speedwell	9.0	1.0	0.3	1.5	2.9						
	Cutleaf eveningprimrose	12.3	–	–	0.6	–						
	Hairy bittercress	33.0	46.9	1.3	10.1	99.0						
	Henbit	44.5	47.5	2.0	12.4	227.9						
	Mouseear chickweed	–	–	6.1	2.9	10.4						
	Mousetail	–	43.1	2.3	–	9.0						
	Water foxtail	29.1	18.5	14.0	20.1	13.2						

[1] Means within columns followed by the same letter are not different (P = 0.05) according to Duncan's Multiple Range Test.

[2] Severe winterkill in December 1983.

[3] Not determined.

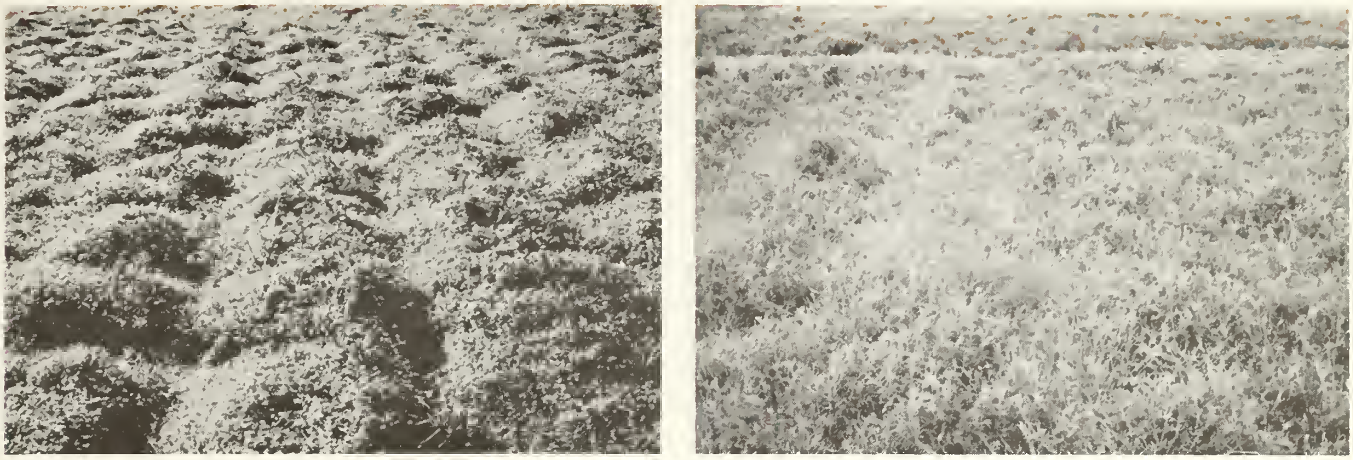

Figure 3. The growth of winter vegetation in the vetch area is pictured on November 21, 1986 (left) and April 6, 1987 (right).

level can be explained by more growth in the late winter and early spring of 1985 when dry conditions prevailed.

The March and April 1987 dry weight yields reflected the very high numbers of wheat, vetch, and winter weeds that emerged during the fall and winter of 1986 (November 1986 counts, Table 2). For an unknown reason, henbit was the species with the greatest number of plants emerging under the conditions of the fall and early winter of 1986-87. The dry weight yields from the March 11 harvest date resulted in greater numerical yield from the vetch and winter weed areas but were not significantly different from those harvested from wheat areas. However, the later harvest on April 8 resulted in significantly higher dry weight from the vetch area when compared to the wheat area.

It is generally accepted that undisturbed areas which allow commonly occurring winter weeds to germinate without benefit of overseeding of cover crops result in less total dry weight in the spring. This occurred in this study with significantly less dry weight than vetch and wheat from the March 1984, April 1985, and March 1986 harvest dates. There were no dry matter yield differences from the April 1983 or the March 1987 harvest dates. The April 1987 harvest date resulted in a dry weight value for winter weeds intermediate between wheat and vetch.

Winter weed species were not different between any of the cover crops areas (Table 2). The outstanding difference among winter weeds species was the very high population of henbit occurring with the November 1986 count. Henbit was among the predominant weed species in 1983, 1984, and February 1986, but at lower levels. Water foxtail, common chickweed, hairy bittercress, and annual bluegrass were present most years at populations that resulted in a predominant position.

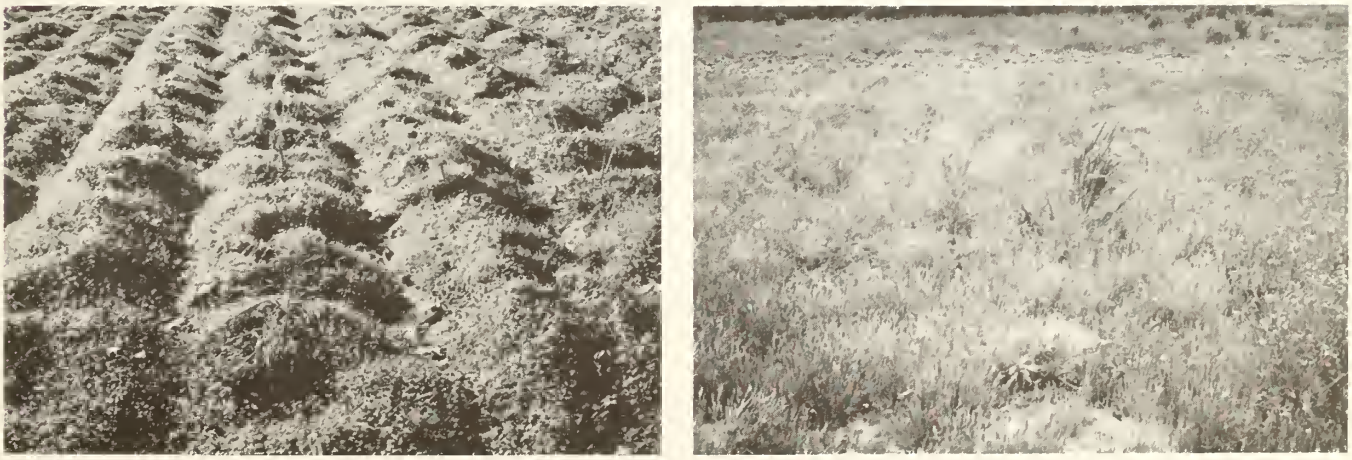

Figure 4. The growth of winter vegetation in the winter weeds area is pictured on November 21, 1986 (left) and April 6, 1987 (right).

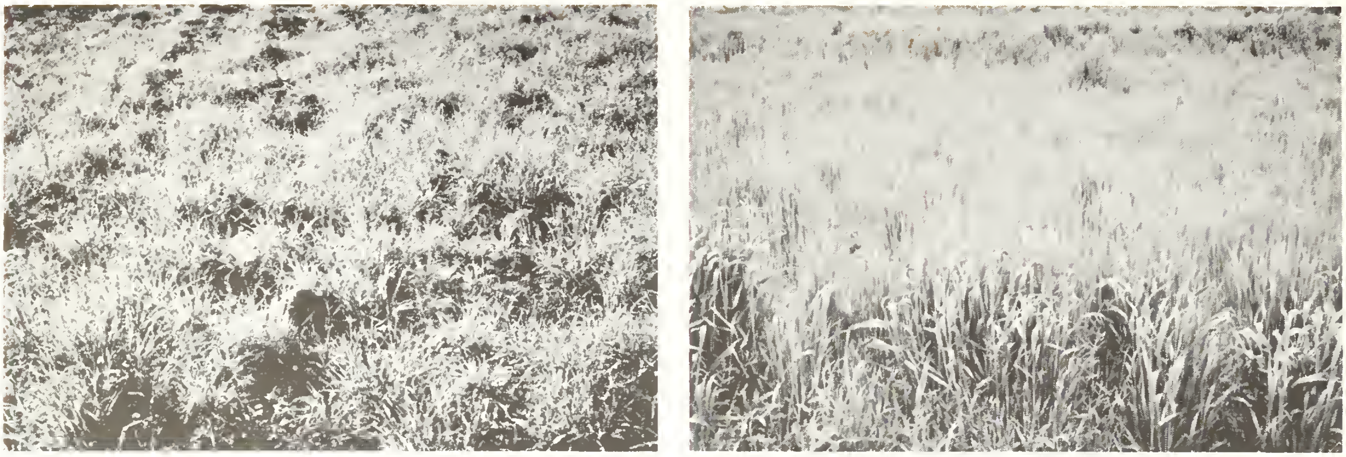

Figure 5. The growth of winter vegetation in the wheat area is pictured on November 21 (left) and April 6, 1987 (right).

Summer weeds

There were no main plot or main plot by subplot treatment interaction differences with any of the summer weed species counts. Individual species are discussed in the following paragraphs.

Entireleaf morningglory
Ipomoea hederacea var. *integriuscula* Gray

Ivyleaf morningglory
Ipomoea hederacea (L.)

Significant subplot treatment differences in numbers of entireleaf/ivyleaf morningglory plants were observed in 1983 and in 1985 through 1987 (Table 3). Highest counts were obtained from plots that had not been treated with any herbicide. In 1985 and 1986, the Bed-Cotoran PRE treatment (4) was not different from the Bed-only treatment (1); and in 1987, plots treated with Roundup/Ignite PPF-Cotoran PRE (2) were not different from the Bed-only treatment (1).

Pitted morningglory
Ipomoea lacunosa L.

Significant differences for pitted morningglory occurred only in 1983 and 1986 (Table 3). In 1983, the Roundup PPF-Cotoran PRE treatment (2) reduced the population from that obtained with the Bed-only treatment (1). In 1986, all herbicide treatments reduced the level of pitted morningglory below that of the Bed-only treatment (1).

Smooth pigweed
Amaranthus hybridus L.

Differences in count numbers for smooth pigweed occurred in each of the 5 years (Table 3). In 1983, and in 1985 through 1987, all herbicide treatments reduced smooth pigweed numbers below those of the Bed-only treatment (1). In 1984, the Roundup PPF-Cotoran PRE treatment (2) did not reduce the number of smooth pigweed plants below that of the Bed-only treatment (1).

Prickly sida
Sida spinosa L.

Prickly sida counts resulted in lower numbers from all herbicide treatments when compared with the Bed-only treatment (1) in all years (Table 3).

Spurred anoda
Anoda cristata (L.) Schlecht.

Spurred anoda did not occur in sufficient numbers to report until 1986 (Table 3). In 1986, there were no differences between counts with any treatment. In 1987, all herbicide treatments reduced the population of spurred anoda below that obtained in the Bed-only treatment (1).

Hyssop spurge
Euphorbia hyssopifolia L.

The population of hyssop spurge was inconsistent and occurred in numbers high enough to report only during 1984 and 1986 (Table 3). In 1984, no herbicide treatment resulted in adequate control probably because of the variable population. Highest numbers occurred with Bed-Cotoran PRE (4), which were significantly greater than the Bed-only (1) or Bed-Treflan PPI-Cotoran PRE (5) treatments. In 1986, hyssop spurge populations were higher and all herbicide treatments reduced the spurge numbers below those obtained with the Bed-only treatment (1).

Table 3. Effect of winter cover crops and production operations on summer weed control as determined by weed counts, by weed species. MAFES Delta Branch, 1983-1987.

Treatment	Entireleaf/ivyleaf Morningglory[1]					Pitted morningglory[1]				
	1983	1984	1985	1986	1987	1983	1984	1985	1986	1987
	(No./15 sq. ft.)					(No./15 sq. ft.)				
Main Plot										
A. Wheat	1.0	0.6	0.5	7.8	4.1	7.3	3.7	2.9	0.9	3.5
B. Vetch	1.8	2.1	0.9	6.3	12.0	2.3	3.5	2.1	1.2	2.3
C. Winter Weeds	0.6	0.3	0.5	5.6	8.0	2.4	2.5	2.1	0.9	3.2
Subplot										
1. Bed only	3.8 a	1.4	1.4 a	11.1 a	14.3 a	6.5 a	2.7	1.8	4.2 a	4.2
2. Roundup/Ignite PPF Bed Cotoran PRE	0.6 b	0.8	0.3 b	5.4 b	11.1 ab	2.3 b	2.4	2.7	0.0 b	2.0
3. Roundup/Ignite PPF Bed Treflan PPI Cotoran PRE	0.5 b	0.9	0.3 b	4.5 b	5.1 b	3.0 ab	4.1	3.0	0.3 b	1.5
4. Bed Cotoran PRE	0.4 b	0.5	0.8 ab	7.7 ab	6.2 b	3.9 ab	4.3	2.0	0.3 b	4.7
5. Bed Treflan PPI Cotoran PRE	0.0 b	1.3	0.3 b	4.2 b	3.2 b	4.1 ab	2.6	2.0	0.2 b	2.7
	Smooth Pigweed					Prickly Sida				
Main Plot										
A. Wheat	0.9 a	0.1	0.3	3.2	6.2	20.0	14.1	1.4	9.2	8.0 a
B. Vetch	5.3 a	1.6	4.8	12.8	8.6	12.4	15.5	3.2	15.5	2.3 b
C. Winter Weeds	0.8 b	0.8	0.3	4.2	2.0	16.6	9.2	2.0	6.2	1.8 b
Subplot										
1. Bed only	10.4 a	3.8 a	6.5 a	33.0 a	27.8 a	68.5 a	47.7 a	6.3 a	41.7 a	17.4 a
2. Roundup/Ignite PPF Bed Cotoran PRE	0.4 b	0.3 ab	0.8 b	0.0 b	0.0 b	2.3 b	2.6 b	0.6 b	1.5 b	2.0 b
3. Roundup/Ignite PPF Bed Treflan PPI Cotoran PRE	0.4 b	0.0 b	0.0 b	0.0 b	0.0 b	4.0 b	5.8 b	1.5 b	0.9 b	0.2 b
4. Bed Cotoran PRE	0.3 b	0.0 b	1.2 b	0.0 b	0.0 b	5.4 b	3.5 b	1.7 b	3.8 b	0.5 b
5. Bed Treflan PPI Cotoran PRE	0.1 b	0.0 b	0.3 b	0.5 b	0.0 b	1.6 b	5.1 b	0.5 b	3.3 b	0.0 b
	Hyssop Spurge					Spurred anoda				
Main Plot										
A. Wheat	–	2.9	–	3.2	–	–	–	–	0.9	7.4
B. Vetch	–	0.8	–	5.4	–	–	–	–	0.6	3.3
C. Winter Weeds	–	0.4	–	3.5	–	–	–	–	0.2	4.4
Subplot										
1. Bed only	–	0.2 b	–	18.0 a	–	–	–	–	1.4	14.7 a
2. Roundup/Ignite PPF Bed Cotoran PRE	–	1.8 ab	–	0.5 b	–	–	–	–	0.2	3.3 b
3. Roundup/Ignite PPF Bed Treflan PPI Cotoran PRE	–	1.6 ab	–	0.5 b	–	–	–	–	0.2	0.8 b
4. Bed Cotoran PRE	–	2.7 a	–	0.2 b	–	–	–	–	0.6	1.2 b
5. Bed Treflan PPI Cotoran PRE	–	0.5 b	–	0.8 b	–	–	–	–	0.3	4.8 b
	Annual grasses									
Main Plot										
A. Wheat	37.8	12.3	2.4	35.6	14.0					
B. Vetch	26.3	12.4	14.9	45.5	24.8					
C. Winter Weeds	33.6	16.1	10.1	29.6	48.2					
Subplot										
1. Bed only	142.5 a	61.9 a	31.1 a	151.7 a	132.8 a					
2. Roundup/Ignite PPF Bed Cotoran PRE	7.9 b	2.5 b	3.0 b	9.8 b	3.5 b					
3. Roundup/Ignite PPF Bed Treflan PPI Cotoran PRE	2.6 b	0.2 b	0.5 b	7.8 b	0.0 b					
4. Bed Cotoran PRE	8.1 b	3.1 b	10.2 b	9.8 b	8.1 b					
5. Bed Treflan PPI Cotoran PRE	1.5 b	0.2 b	0.9 b	5.4 b	0.2 b					

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[1] Means within columns for main-plot treatments and subplot treatments followed by the same letter are not different ($P = 0.05$) according to Duncan's Multiple Range Test. PPF = preplant to cover-crop foliage; PPI = preplant incorporated shallow; PRE = preemergence.

Annual grasses

Broadleaf signalgrass
***Brachiaria platyphylla* (Griseb.) Nash**

Browntop panicum
***Panicum fasciculatum* Sw.**

Barnyardgrass
***Echinochloa crus-galli* (L.) Beauv.**

Populations were extremely high in most years with the Bed-only treatment (1). All herbicide treatments had fewer annual grass plants when compared with the Bed-only treatment.

Hoe time

Hoe time for 1984 ranged from 10.1 to 15.3 hours per acre for subplot herbicide treatments (data not presented). These times were lower than that for the Bed-only treatment (43.1 hours per acre). In 1985, valu es were much higher, ranging from 61.8 to 92.3 hours per acre for the subplot herbicide treatments. Again, these were lower than the Bed-only treatment (211.0 hours per acre). Only subplot treatment means were significantly different.

Cotton stand

The stands of cotton determined shortly after emergence were less than adequate in 2 of 5 years (1983 and 1985 –Table 4). Cotton stand was considered marginal in 1984 and 1986. Only in 1987 was the stand adequate. Averaged over subplot treatments, significantly fewer cotton plants emerged on the vetch and winter weeds areas than on the wheat area in 1983. In 1985, reduced stands occurred only on the vetch area. In 1987, fewer cotton plants emerged on the wheat area than on the vetch and winter weeds areas. However, cotton stand for all main plot areas in 1987 was sufficient to produce maximum yield. In 1984 and 1986, there were no differences in cotton stand with any of the main plot treatments.

There were no main plot by subplot interactions for cotton stand. Subplot treatments did not result in cotton stand differences in 1983 (Table 4). Cotton stand differences were observed in 1984 through 1987 with subplot treatments. The Roundup PPF-Bed-Treflan PPI-Cotoran PRE treatment (3) resulted in cotton plant counts higher than those obtained from the Bed-only treatment (1) in 1984. In 1985, the same treatment along, with Roundup PPF-Cotoran PRE (2), resulted in greater stands than the Bed-only (1) or Treflan PPI-Cotoran PRE (5) treatments. Stands in 1985 were considerably below those considered minimal for adequate production. In fact, the highest number of cotton plants (14,300 plants per acre) was only about 40% of what would normally be considered a minimum stand for this soil type. Stand differences in 1986 followed the same trend as were obtained in 1985. In 1987, Roundup/Ignite PPF-Bed -Treflan PPI-Cotoran PRE (3) resulted in a greater cotton stand than the Bed-only (1), Bed-Cotoran PRE (4), and Bed-Treflan PPI-Cotoran PRE (5) treatments. All subplot treatments in 1987 produced an adequate stand for optimum yield.

Table 4. Effect of winter cover crops and production operations on stand of cotton. MAFES Delta Branch, 1983-1987.

Treatment	Cotton Stand				
	1983	1984	1985	1986	1987
	(Plants/A in thousands)				
Main Plot[1]					
A. Wheat	29.3 a	31.2	14.6 a	27.6	42.0 b
B. Vetch	18.7 b	31.9	5.8 b	30.0	55.2 a
C. Winter Weeds	23.1 b	33.6	14.2 a	30.4	57.2 a
Subplot[1]					
1. Bed only	25.2	25.4 b	9.0 b	25.2 b	48.7 b
2. Roundup/Ignite PPF Bed Cotoran PRE	27.1	32.1 ab	14.0 a	33.6 a	54.1 ab
3. Roundup/Ignite PPF Bed Treflan PPI Cotoran PRE	23.0	35.6 a	14.3 a	34.9 a	56.4 a
4. Bed Cotoran PRE	21.7	34.2 ab	11.9 ab	28.0 ab	49.3 b
5. Bed Treflan PPI Cotoran PRE	21.4	34.0 ab	8.5 b	25.0 b	48.9 b

[1] Means within columns followed by the same letter are not different (P = 0.05) according to Duncan's Multiple Range Test. PPF = preplant to cover crop foliage; PPI = preplant incorporated shallow; PRE = preemergence.

Seed cotton yield

The wheat main plot treatment resulted in lower yields in 1986 and 1987 (Table 5). There were no main plot or main plot by subplot yield differences in 1983 and 1984. Seed cotton yield in 1985 resulted in a significant main plot by subplot treatment interaction.

When averaged over main plot treatments in 1983, all herbicide subplot treatments resulted in greater yield than the Bed-only treatment (1) with the Bed-Treflan PPI-Cotoran PRE treatment (5) greater than the other herbicide treatments. In 1984, 1986, and 1987 all herbicide treatments resulted in greater yield than the Bed-only treatment (1). Also in 1984, the yield from the Roundup PPF-Bed-Treflan PPI-Cotoran PRE treatment (3) resulted in greater yield than that obtained with the Bed-Cotoran PRE (4) treatment. In 1986 and 1987, there were no seed cotton yield differences among treatments using herbicides.

Talbe 6 presents the seed cotton yield means for the 1985 main plot x subplot interaction. No differences occurred between cover crops with the Bed-only subplot treatment. Within the Roundup PPF-Bed-Cotoran PRE subplot treatment, each main plot treatment resulted in seed cotton yields different from the other. The highest yield was harvested from the winter weeds area, an intermediate yield was harvested from the wheat area and the lowest yield was from the vetch area. With the subplot treatment of Roundup PPF-Bed-Treflan PPI-Cotoran PRE, lowest yield was obtained from the vetch area, which was significantly different from each of the other main plot treatments. With the Bed-Cotoran PRE subplot treatment, yield from the winter weeds area was significantly greater than yield from each of the other areas. There were no differences in yield between the three cover crops with the subplot treatment of Bed-Treflan PPI-Cotoran PRE.

When subplot treatments are compared within a main plot treatment (Table 6), it is found that with wheat as the cover crop, highest yield was obtained with Roundup PPF-Bed-Treflan PPI-Cotoran PRE. The lowest seed cotton yield was obtained from the Bed-only treatment but this was not significantly lower than the yield obtained from the Bed-Cotoran PRE treatment. Within the vetch main plot treatment, higher yields resulted from all herbicide treatments when compared to the Bed-only treatment. There were no differences among the herbicide subplot treatments. Within the winter weeds main plot treatment, lowest yield was obtained from the Bed-only treatment, the next lowest yield was obtained with the Bed-Treflan PPI-Cotoran PRE treatment. The remaining subplot treatments resulted in highest yields and were not different.

Summary and Conclusions

Cotton was grown after three cover crops (wheat, vetch, winter weeds) for 5 years (1983-1987). The winter vegetation was characterized by indigenous species and was not altered by the herbicide treatments used. Preplant foliar application of Roundup or Ignite to the cover crops did not make it easier

Table 5. Effect of winter cover crops and production operations on seed cotton yield. MAFES Delta Branch, 1983-1987.

	Seed Cotton Yield				
Treatment	**1983**	**1984**	**1985[2]**	**1986**	**1987**
	(lb/A)				
***Main Plot*[1]**					
A. Wheat	674	574	1,008	926 b	1,244 b
B. Vetch	500	482	489	1,191 a	1,863 a
C. Winter Weeds	743	804	1,377	1,180 a	1,671 a
***Subplot*[1]**					
1. Bed only	71 c	367 c	306	266 b	246 b
2. Roundup/Ignite PPF Bed Cotoran PRE	704 b	729 ab	1,289	1,363 a	1,964 a
3. Roundup/Ignite PPF Bed Treflan PPI Cotoran PRE	749 b	776 a	1,355	1,401 a	1,964 a
4. Bed Cotoran PRE	674 b	566 b	977	1,202 a	1,743 a
5. Bed Treflan PPI Cotoran PRE	998 a	662 ab	863	1,263 a	2,046 a

[1] Means within columns followed by the same letter are not different ($P = 0.05$) according to Duncan's Multiple Range Test. PPF = preplant to cover crop foliage; PPI = preplant incorporated shallow; PRE = preemergence.

[2] A significant cover crop x herbicide treatment interaction. See Table 6 for mean separation.

Table 6. Effect of winter cover crops and herbicide treatments on seed cotton yield from plots used to grow cotton with the production operations presented in Table 1. MAFES Delta Branch, 1985.

	Subplot treatments[1]				
Main-plot treatments	Bed only	Roundup Bed-Cotoran[1]	Roundup Bed-Treflan Cotoran	Bed-Cotoran	Bed-Treflan Cotoran
	(lb/A)				
A. Wheat	392 aD	1,254 bB	1,752 aA	703 bCD	940 aBC
B. Vetch	57 aB	633 cA	711 bA	684 bA	560 aA
C. Winter Weeds	470 aC	1,981 aA	1,601 aA	1,744 aA	1,090 aB

[1] Means within colums followed by the same lower case letter or within rows followed by the same capital letter are not different (P=0.05) according to Duncan's Multiple Range Test.

to perform subsequent preplant tillage operations. The winter vegetation did not interfere with spring re-bedding or planting operations nor with incorporating Treflan on top of the bed with a bed conditioner. The cover crops did not affect the composition and control of summer weeds.

All herbicide treatments provided acceptable control of summer weeds. Cotton stand was less than acceptable in 2 of 5 years (1983 and 1985) and in 1985 the stand was reduced 59% on the vetch area. Seed cotton yield was not affected consistently by the type of winter cover but seed cotton yield was lower with reduced plant population, especially in 1983 and 1985. Seed cotton yields from herbicide treatments ranged from 409 (1984) to 1,800 pounds per acre (1987) more than yields from plots without herbicides.

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Fescue, Fescue-Clover, and Ryegrass for Stocker Production and Profitability

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Fescue, Fescue–Clover, and Ryegrass for Stocker Production and Profitability

Introduction

Cool season pastures of either annual ryegrass or tall fescue have been the basic forage for beef stocker operations in the southeastern United States for many years. Since the discovery that infestation of tall fescue (*Festuca arundinacea* Schreb.) by the endophyte fungus, *Acremonium coenophialum*, reduced performance and economic return of stocker cattle, efforts have been made to determine the best management procedures to improve performance of stocker cattle grazing tall fescue. Endophyte-free fescue (EFF) pastures require higher levels of management in the lower South because of the decreased hardiness of the grass and poor stand persistence.

Decisions on whether to destroy the endophyte-infested fescue (EIF) pastures or continue to use the more expensive annual ryegrass (RG) in Mississippi and other southeastern states must be based on sound economics if beef cattle producers expect to maintain profitable operations. Thirty years ago, researchers were showing the benefits of cool season forages for the production of gain even in finishing beef cattle (Williams and Edgar, 1959). Yet Hoveland (1986) stated that beef production in the southeastern United States, as elsewhere, is basically an inefficient enterprise. He further stated that this inefficiency is illustrated by the very low beef production obtained per acre by average cattle producers in the region.

Many desirable characteristics of tall fescue as a cool season forage allow its extensive use as a pasture for beef cow-calf and stocker operations in the southeastern United States (Standaert, 1986; Ball et al., 1987; Smith et al., 1987). Those characteristics include a long growing season, stand persistence, limited management requirements, high dry matter (DM) yield, and drought tolerance.

Initially, it appeared that most, if not all, the tall fescue pastures in the southern United States were infected with *A. coenophialum* (Ball et al., 1987; Evans, 1985). The problem was compounded when it was determined that seeds and hay from infested stands were also infected with the fungus and would cause the same symptoms when fed to cattle (Boling, 1985; Schmidt et al., 1982). Early results indicated much improved performance for cattle grazing the fescue with low or no endophyte fungus present (Burton, 1986; Standaert, 1986; Essig et al., 1987; Stuedeman et al., 1988; McMurphy et al., 1988). However, EFF pastures did not produce as much total forage yield as the EIF pastures nor were they as stress tolerant (Siegel et al., 1987a; Siegel et al., 1987b; West, 1987; Wilkinson, 1987).

Experimental Procedures

In the fall of 1984, five paddocks in each of two 25-acre pastures located on the Animal Research Center at Mississippi State were to one of five forages or forage mixtures: Marshall ryegrass; Ky-31 EFF; Ky-31 EFF, plus red (*Trifolium pratense*) and subterranean (*Trifolium subterraneum* L.) clover (EFFC); Ky-31 EIF; or Ky-31 EIF, plus red and subterranean clover (EIFC). Infection levels were checked on all fescue paddocks during each year of the trial. Results are shown in Table 1.

The ryegrass pastures were planted between September 1 and September 10 each year of the experiment. Appropriate tall fescue or tall fescue-clover combinations were planted using a no-till drill. Due to a poor EFF stand, extra EIF seed was applied, in error, to one paddock (No. 19-5) in fall 1985. Because of the mixed seeding, the results of the performance on this paddock were not included in statistical analysis.

All pastures were fertilized in the fall and spring with ammonium nitrate at the rate of 200 lb/acre for ryegrass, EFF, and EIF pastures, and 100 lb/acre for the pastures containing clover. The intent throughout the trials was minimum intervention with minimum supplemental feeding to provide the most economical gain for a typical stocker producer in the southeastern United States.

The first year was extremely dry

Table 1. Endophyte Infestation Levels.

	Paddock and forage									
Year	19-1 EIF	19-2 EIF	19-3 RG	19-4 EFF	19-5 EFF	20-1 RG	20-2 EFF	20-3 EIF	20-4 RG	20-5 EIF
1	27	32	0	0	0	0	0	26	0	33
2	47	67	0	0	24**	0	0	43	0	46
3	88	82	0	0	36**	0	0	68	0	73

* Percent of tillers infested.

**Supplemental EIF seed erroneously applied fall 1985 due to loss of stand in this paddock only.

and calves were not placed on pasture until March. For years 2 and 3, a November start date was selected when forage tiller height had reached approximately 10 inches. Comparisons of forage yield for each treatment were made during each trial. Duplicate cages, 4 feet square by 2 feet deep were placed in each paddock in areas of typical forage coverage and growth. Clippings from each cage were collected on each weigh day throughout the experiment.

Experimental Animal Selection

Criteria for selection of experimental weanling heifers were age, weight, and breed. Breeds were Hereford, Angus, Charolais, Santa Gertrudis, F1 (Angus x Brahman), and three-breed crosses (Angus x Brahman x Hereford). In all cases, the number in each breed classification allowed equal placement in each complete block so that all paddocks had equal numbers of each breed. Stocking rate for all years was seven animals on each 5-acre paddock or 1.4 animals per acre.

Economics

In calculating the returns per unit area, the following assumptions were made: (1) Cost of animals for all treatments were equal since the heifers were randomly assigned to all treatments in equal numbers; (2) Cost of management practice were equally applied to all treatments; (3) The value of gain per unit of weight was equal for animals on all treatments since the animals were balanced by breed and randomly assigned.

An economic evaluation for each trial was calculated using the following procedures: (1) total gain for each treatment was calculated; (2) cost to establish or maintain the forage in each treatment was calculated using appropriate cost from budgets developed by the Mississippi Agricultural and Forestry Experiment Station and Mississippi Cooperative Extension Service for the year in question (MAFES/MCES, 1985; 1986; 1987); (3) supplemental feeding required to maintain animals when forage was unavailable was determined using the following: year 1 – none used; year 2 – shelled corn at $1.75/bu, soybean meal at $210/T, mineral premix at $14.56/cwt, salt at $5.00/cwt, and 1,200-lb large round bales of hay at $20.00 each; year 3 – hay fed to animals on pasture as needed. The diet for year 2 (excluding hay) cost $110.40/T. Because all animals were pooled in a common nontreatment pasture during periods of supplemental feeding in year 2, the cost of that feeding was equally divided among treatment groups.

The following formula was used to compute profit (loss) for each treatment: Profit(loss)/acre = (ADG x number animals x grazing days x $.60) – (cost of maintenance + cost of supplemental feed).

In Vitro Dry Matter Disappearance

Samples of the forages for the spring and summer growing periods for 1987 were retained. An *in vitro* dry matter disappearance (IVDMD) procedure (Goering and Van Soest, 1970) was used to simulate the digestibility of these forages.

Statistical Analysis

Weigh data collected each 28 days were analyzed using the general linear model (GLM) of the Statistical Analysis System (SAS, 1985). The model was a split-plot design using forage as whole plot effect with weigh period as sub-plot effect. Whole plot effect was tested using forage by block mean square as error. The LSD procedure was used to separate means that were significantly different.

Results and Discussion

Year 1

Dry matter (DM) yields for year 1 (Table 2) were measured on the day the calves were placed in the pastures and each 28 days thereafter. Yields were calculated to make comparisons with animal gain for that 28-day period. Even though the ryegrass pastures had begun to deteriorate by the last weight period, there was no great divergence in yield for all treatment forages. Loss of clover from two of the treatments was expected after reviewing research by Standaert (1986). The clover loss occurred after the first year of grazing.

During year 1, there was no difference in DM yields among treatments; however, the gains of the test animals across treatments were different (Table 3). Test animals were removed from the paddocks containing ryegrass after period 3 (May 6) because the volume of forage was insufficent to maintain economical gain. The ryegrass forage under protection of the cages was harvested on June 3 and July 2 even though there were no animals on the paddocks. The DM:gain ratio shows a relationship between total forage yield and gain per acre. The smaller ratios

Table 2. Dry matter yield for the forage systems, Year 1.

	Treatments, lb DM/acre				
Date	RG	EFF	EFFC	EIF	EIFC
Mar 12	1,582	1,415	995	1,240	1,260
Apr 9	892	1,189	988	1,192	976
May 6	672	638	1,090	910	857
June 3	418	306	674	388	431
July 2	148	527	487	742	403
Mean*	742	815	847	895	785

*Means not significantly different.

for ryegrass and EFIC indicate more efficient use of forage produced. Profit per acre was higher for all fescue treatments than for the ryegrass even though gain per acre was higher for ryegrass. This fact was amplified by the longer growing season for the fescue treatments and the additional gain per acre as a result. The higher cost of establishing the ryegrass pastures and the short 84-day grazing period were principal causes.

Year 2

Early growth of forage in 1985 allowed placement of heifers in paddocks in late fall as the original plan dictated. After evaluation of the forage growth in November 1985, the decision was made to place the heifers on pasture November 25.

Evaluation of growth of the forage in the experiment began with a harvest of the forage under cages on each weigh day except for those when growth was insufficient for measurement. Total DM yields were calculated for each 28-day period (Table 4). The DM yields among forages show very little difference through the growing season.

Gain per acre among treatments shows the first major measureable effect of the endophyte fungus with gains for the ryegrass and EFF being significantly larger than gains of infested pastures. Even though there was no difference in forage yield, the ratio of DM yield to gain reflected the low per acre gain of animals on EIF. The lower gain per acre was reflected in lower profit per acre for heifers grazing the EIF, even though it (EIF) was less expensive to maintain than to establish and maintain ryegrass. Performance during year 2 was the first suggestion of the detrimental effect of endophyte on cattle. An evaluation of returns per acre using the formula stated earlier showed the returns for animals grazing ryegrass and EFF to be superior to those grazing EIF (Table 5).

Year 3

Measurements of the DM yields of forage harvested from cages indicated excellent forage growth for the entire season. The EIF pro duced the most total DM yield per acre (Table 6). Lack of consistent production was very evident when the average DM yield per period was computed for the different forages. The EIF produced an average of 54% more forage per acre than did EFF and 60% more

Table 3. Total animal gain, forage yield, grain yield ratio, and economic calculations, Year 1 in all forage systems (84 days and 140 days).

	Treatments				
Item	RG	EFF	EFFC	EIF	EIFC
No. animals	14	14	14	14	14
Init wt., lb.	609	613	619	623	618
Cost, $/ac	145.77	81.10	100.85	81.10	100.85
84-day					
Gain, lb/ac	272.9a	203.4b	236.0ab	204.2b	254.9ab
ADG, lb	2.32	1.73	2.01	1.74	2.17
DMyld, lb/ac	3,146	3,242	3,073	3,342	3,093
DM/gain	11.53	15.94	13.02	16.36	12.13
Profit, $/ac	17.97	40.29	40.75	41.42	52.09
140-day					
Gain, lb/ac		245.0ab	279.4a	230.8b	287.4a
ADG, lb		1.75	2.00	1.65	2.05
DM yld, lb/ac		4,075	4,234	4,472	3,927
DM/gain		16.63	15.15	19.38	13.66
Profit, $/ac		65.90	66.79	57.38	71.59

*Means within a row with a different letter differ significantly ($P<.05$).

Table 4. Dry matter yields, Year 2.

	Treatments, lb DM/acre		
Date	RG	EFF	EIF
Nov 25	1,955	2,075	2,033
Dec 17	400	606	592
Mar 17	474	382	446
Apr 14	1,077	841	917
May 12	512	427	437
Mean*	885	866	885

* DM yields not significantly different.

Table 5. Total animal gain, forage yield, gain yield ratio and economic calculations, Year 2 (196 days)

	Treatments		
Item	RG	EFF	EIF
No. animals	14	28	28
Init wt. lb.	516	516	533
Gain, lb/ac	395a	362a	209b
ADG, lb	1.44	1.32	0.76
DM Yield, lb/ac	4,418	4,331	4,425
DM/Gain, lb	11.18	11.96	21.17
Cost, $/ac	137.81	86.39	86.39
Profit, $/ac	99.19	130.81	39.01

[a,b] Means within a row followed by a different letter differ significantly ($p<.05$).

total DM yield suggests that the fungus adds hardiness to the EIF cultivar. Dry matter yield was considerably higher for EIF during May, June, and July than for EFF.

Gain per acre values were more different during year 3 than year 2. Animals on ryegrass produced significantly more gain than those on either of the other treatments (Table 7). Likewise, the heifers that grazed EFF gained more than those allowed to graze EIF. Differences in forage yield increased the DM:gain ratio with ryegrass and EFF showing much more efficiency. Higher gain per acre for ryegrass generated more gross income, but the additional cost of establishment and maintenance resulted in a higher net income attributed to EFF. Likewise the lower gain per acre for EIF animals resulted in the lowest net return for all treatments. Even though the EIF forage was lush and had the highest DM yield the test animals performed poorly.

Whatever is causing poor animal performance might be causing lower digestibility of the forage or decreased intake and thus providing animals with less energy. Samples from all treatment forages for the spring and summer growing season in year 3 (1987) were evaluated using the *in vitro* dry matter digestibility (IVDMD) procedures (which simulates rumen dry matter digestibility using microbial fermentation in a laboratory apparatus), to determine if the endophyte fungus reduced dry matter digestibility (Goering and Van Soest 1975).

There were no significant differences in the IVDMD values of the forages indicating little or no effect of the endophyte on DM digestibility (Table 8). These data are in agreement with data of Fribourg (1987) who showed only a small decrease for in vitro digestibility of EIF versus EFF forage, Schmidt et al. (1982), Bush and Burris (1988), and Burton (1986) who showed no change in IVDMD as a result of endophyte infestation.

Table 6. Dry matter yields, Year 3.

	Treatments, lb DM/acre		
Date	RG	EFF	EIF
Nov 10	733	1,604	1,997
Dec 5	377	295	341
Jan 5	134	139	184
Mar 27	1,658	792	1,128
Apr 24	709	555	587
May 21	2,082	2,460	4,212
June 19	1,408	1,932	3,326
July 17	147	144	564
Mean*	915a	990a	1,515b

* Means within a column followed by a different letter differ (p<.05).

Table 7. Total animal gain, forage yield, gain yield ratio, and economic calculations, Year 3 (252 days).

	Treatments		
Item	RG	EFF	EIF
No. animals	14	28	28
Initial wt.	461	467	466
Gain, lb/ac	427a	366b	306c
ADG, lb	1.21	1.04	0.87
DM yield, lb/ac	7,248	7,931	12,139
DM/gain, lb	16.97	21.35	39.67
Cost, $/ac	125.62	78.98	78.98
Profit, $/ac	134.78	143.02	102.82

*Means within a row foll owed by a different letter differ (P<.05).

Table 8. In vitro dry matter disappearance values of forage systems, Year 3*.

Forage	Minimum	Maximum	Mean	SD
		%		
RG	47.34	88.35	68.99	12.57
EFF	40.67	83.10	64.67	8.34
EIF	46.66	82.24	65.02	9.08

* Values are % DM disappearance

Summary

The addition of clover to EIF pastures appeared to increase the gain and economic return of stocker cattle on such pastures. Normally, one could expect 2 to 3 years or more of clover production under good management; however, virtually all the clover in these trials disappeared after the first year. Drought was blamed for the clover loss and has occurred with some regularity. Atypical environmental conditions, such as drought, reduced the economic return on all treatments but were especially harmful to the ryegrass pasture because of the high expense of initial establishment. There was a large increase in the ratio of DM yield to gain over 3 years for heifers grazing the EIF treatment. This led us to conclude that intensity of endophyte infestation also increased with the age of stand.

Results of both animal performance and profitability in these trials build a strong case for con tinued use of annual ryegrass and (or) EFF as a primary source of the total diet for stocker cattle in the southeastern United States. The amount of rainfall at planting or shortly after, along with winter temperatures are major factors in determining the economics of stocker production.

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Effect of Sprinkler Irrigation on Open Cotton Flowers

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Effect of Sprinkler Irrigation on Open Cotton Flowers

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Abstract

Sprinkler irrigations between sunrise and noon, on white, open cotton flowers reduced flower retention to about 35 percent of the retention of flowers not watered during the same period. Flower retention gradually increased as the timing of irrigation changed from noon to late afternoon. A similar reduction in boll set was induced by rain. Field and greenhouse experiments were conducted to estimate the potential effect of this type of fruiting losses on cotton yields. From 14 to 66 percent of the fruiting structures were removed by hand to simulate flower loss caused by sprinkler irrigation. Fruiting structures were removed as squares once a week or as white open flowers one, two, or three times a week. Results from the different methods of fruiting structure removal were similar.

Lint yields were 97.5, 95.5, 91.0, 88.2, and 74.1 percent of controls (no fruiting structures removed) for 14, 29, 33, 42, and 66 percent hand removal of fruiting structures, respectively. The lint yields, as percent of control, fit a quadratic regression of the form of $Y = 99.94 - 0.069P - 0.005P^2$ where Y = lint yields in grams per 0.001 acre, P = percent of fruiting structures removed. Sequential hand harvesting showed that flower removal delayed crop maturity by only 1 to 2 days.

These yield reductions for experimental plots may not directly indicate the magnitude of possible yield losses for large production center pivot irrigated fields. Additional calculations of expected yield losses in production fields from the increased bloom abortion caused by water on open cotton flowers showed that watering two or three times a week can result in no more than 1 or 2.2 percent, respectively, lint yield reduction in a production field. These results indicate that production sprinkler irrigation systems should not be turned off during the mornings to recover these small yield losses if there is any possibility that the crop could become water stressed due to the reduction in the amount of water that could be applied.

Effect of Sprinkler Irrigation on Open Cotton Flowers

Introduction

Irrigation of cotton is rapidly developing in the Midsouth. Many producers are installing center pivot sprinkler systems, which represent a good compromise of operating cost, flexibility, and capital investment. General indications are that the use of sprinkler irrigation systems will continue to expand in cotton production. Farmers who install these systems will be faced with many new management decisions and will need to develop an understanding of the interactions of soils, weather, the cotton plant, and irrigation.

With the adoption of sprinkler irrigation systems, many producers have noted that water from sprinkler irrigation or rainfall on open white cotton flowers can result in reduced retention of those flowers. Experiments were conducted to determine the effect of sprinkler irrigation and rainfall on cotton flower retention and cotton yields. The data are reported in two sections. The first experiments determined the effect of sprinkler irrigation and rainfall on flower retention and the second experiments determined the effect of flower loss on cotton yields. This information is then used to estimate the potential impact of any flower loss caused by irrigation on yields in commercial production fields.

Materials and Methods

(A) Effect of Sprinkler Irrigation and Rainfall on Flower Retention

Two field experiments were conducted in 1985 and five field experiments were conducted in 1986 to determine the effect of sprinkler irrigation on the retention of open cotton flowers in the Mississippi Delta. The experiments were conducted under center pivot sprinklers on farms at Belzoni, Silver City, Leland, Sumner, and Glendora, (seven tests total).

Planting dates in the test fields ranged from late April to early May. Stoneville, Delta and Pine Land, and DES short staple cotton varieties were used. Variety differences were not considered. Irrigation began shortly after first flower in late June or early July. Irrigations were usually made at 4-day intervals with 0.8 to 1 inch of water per application. General cultural practices were typical for this area.

In each experiment, 10 flowers were tagged at each of 15 to 25 sites located in an arc around the center pivot (Figure 1). Fruiting structures were tagged on the day before an irrigation as unopened flowers that would open on the day of the irrigation. On the same day, most large bolls were removed from tagged plants to improve the total retention of tagged flowers (Ehlig and LeMert, 1973; Patterson et al., 1978; Guinn and Mauney, 1984).

On the day of the irrigation, the time that the sprinkler passed over an individual site was recorded. Ten to 15 days after the irrigation, the number of tagged flowers remaining on the plants as bolls was recorded at each tagging site. Most boll abscission occurs before bolls are 10 days old (Guinn, 1982). The effect of irrigation on flower retention was determined as the percentage of tagged flowers that formed bolls.

At the end of the season the tagged bolls remaining on the plants were hand-harvested at the Leland location in 1985, and the Sumner location in 1986. The seed cotton from individual bolls was weighed. Each lock of each boll harvested was weighed and the number of mature seeds were counted in 1986.

In 1986, in a separate experiment on the Delta Branch Experiment Station, flowers were tagged in

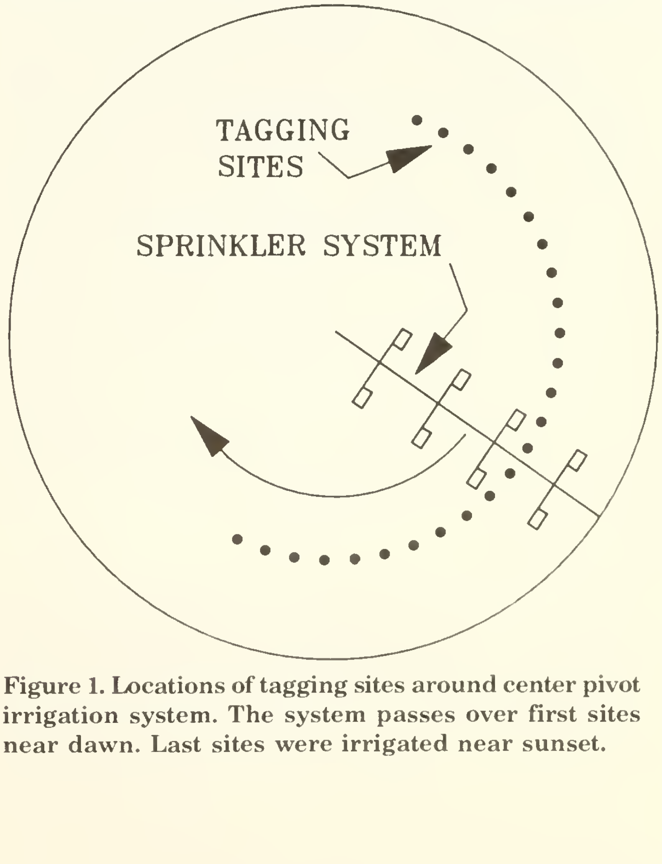

Figure 1. Locations of tagging sites around center pivot irrigation system. The system passes over first sites near dawn. Last sites were irrigated near sunset.

four 0.001-acre plots on the days preceding, during, and after the passage of a weather front (June 27 to July 14), which brought 2 inches of rain during the morning and afternoon of July 2. Approximately 21 days after the rain, the number of tagged flowers that developed into bolls was recorded.

(B) Effect of Fruiting Structure Removal on Cotton Yields

Fruiting structure removal experiments were conducted in the greenhouse in 1982 and 1984, and in the field in 1984 and 1986, on the Delta Branch Experiment Station to determine the effect of partial fruiting structure removal on cotton yields. Fruiting structure loss was obtained by manually removing flowers or squares by the methods described below.

Cultural practices

In the two greenhouse experiments, cotton ('Stoneville 213') was planted on June 28, 1982, (greenhouse experiment 1) and Jan. 24, 1984, (greenhouse experiment 2). Plants were grown in 4-gallon pots containing soil, sand, and peat moss mixed in a 2:2:1 ratio. Supplemental light was supplied by ten 400-W multivapor lamps that delivered a photosynthetic photon flux density of 300-μmol m^{-2} s^{-1} at plant height. A commercially available liquid fertilizer (N-P-K) was routinely applied to the soil mix during the experiments. Insects were controlled with soil applications of Temik® [2–methyl–2–(methylthio)proprianaldehyde–0–(methyl–carbamoly)oxime] and with topical applications of Kelthane® [1,1–Bis(chlorophenyl)–2,2,2–trichloroethanol].

Field experiments were planted on May 11, 1984 (field experiment 1), April 30, 1986 (field experiments 2 and 3), and April 28, 1986 (field experiment 4). Rows were spaced 40 inches apart and plant populations were approximately 3 plants per foot of row. Single row plots in field experiment 1 were 6.5 feet long and in field experiments 2, 3, and 4 were 13.25 feet long. Field experiment 1 was drip irrigated. Field experiments 2, 3, and 4, were sprinkler irrigated with a linear move system. Sprinkler irrigations were applied between 7:00 p.m. and 6:00 a.m. to avoid flower abortion caused by water on open flowers. All other cultural practices were those conventionally used to grow cotton in the Mississippi Delta.

Treatments

Squares were removed from both greenhouse experiments and field experiment 1 at weekly intervals starting during early square development and continuing throughout the active growth period of the plants. The squares were removed at rates of 0, 33, and 66 percent of those that had formed on the plants in the week since the previous square removal. The squares were removed in an unbiased manner with respect to their size and position on the plant.

In field experiments 2, 3, and 4, all white open flowers were removed from the plants 0, 1, 2, or 3 times a week on a Monday, Wednesday, Friday schedule. This resulted in fruiting structure removal percentages of 0, 14, 29, and 43 percent. White flower removal started on July 9, 1986. At this time, there were about two flowers per 13.25 feet of row (0.001 acre). Flower removal continued until mid-August. The flower removal period covered the typical cotton irrigation season for the Mississippi Delta and also represents the major portion of the productive cotton flowering period in this region.

Seed cotton harvesting

Seed cotton from all experiments was hand harvested. Harvest of seed cotton from open bolls was made a single time 145 days after planting in greenhouse experiment 1 and twice, 117 and 140 days after planting, in greenhouse experiment 2. Field experiment 1 was also harvested twice, 148 and 175 days after planting, (Oct. 6 and Nov. 2). Field experiments 2, 3, and 4 were sequentially harvested at weekly intervals from late August until early October. In all experiments, the number of bolls harvested and the total weight of the seed cotton were recorded. Seed cotton was ginned on a table top gin to determine lint percent and lint yields.

Experimental designs and statistical analysis

Both greenhouse experiments were completely randomized with six replications in greenhouse experiment 1 and five replications in greenhouse experiment 2. Field experiments were randomized blocks with five replications in field experiment 1 and six replications in field experiments 2, 3, and 4. Values of least significant difference at alpha = 0.05 were determined using the Waller-Duncan K-ratio method to measure differences among treatments.

Results and Discussion

(A) Effect of Sprinkler Irrigation and Rainfall on Flower Retention

The average of all seven irrigation flower tagging experiments is shown in Figure 2. Retention of open, white flowers that were wetted by the sprinkler irrigation in the morning (7:00 a.m. to noon), just as flowers were opening, was reduced substantially in comparison with flowers wetted pre-dawn or very late in the afternoon. Starting at noon, flower retention gradually increased throughout the afternoon. Data

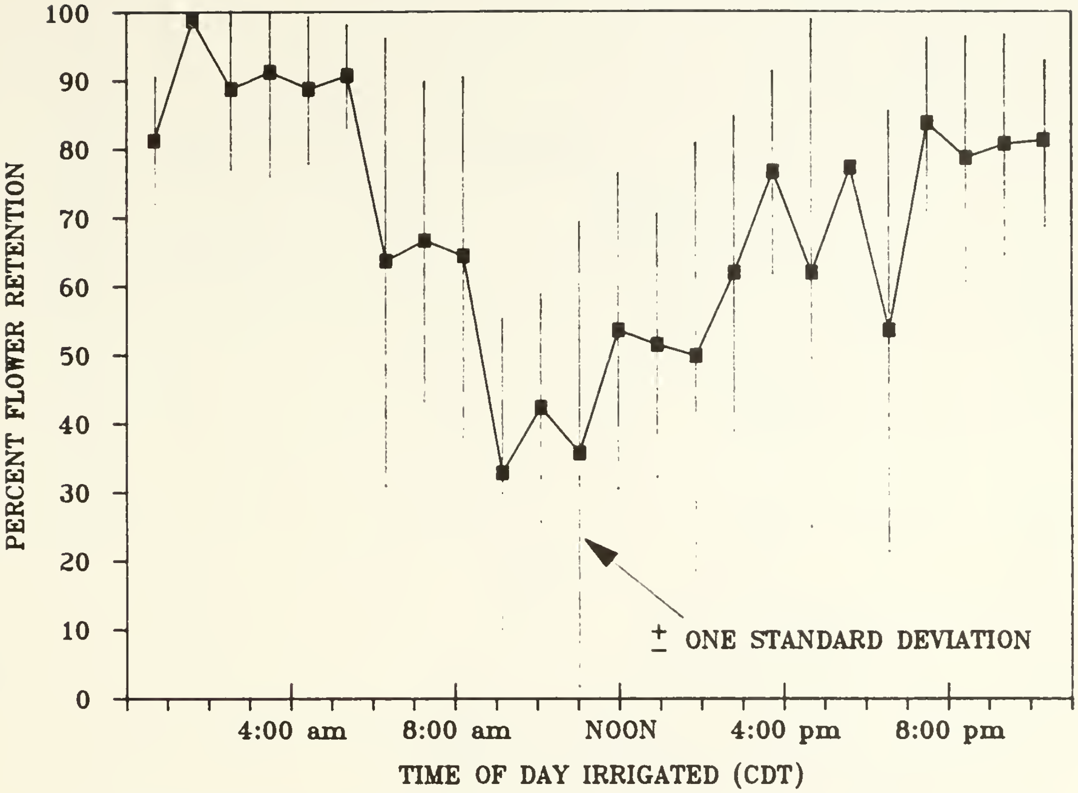

Figure 2. Average flower retention under center pivot irrigation for seven experiments from 1985 and 1986.

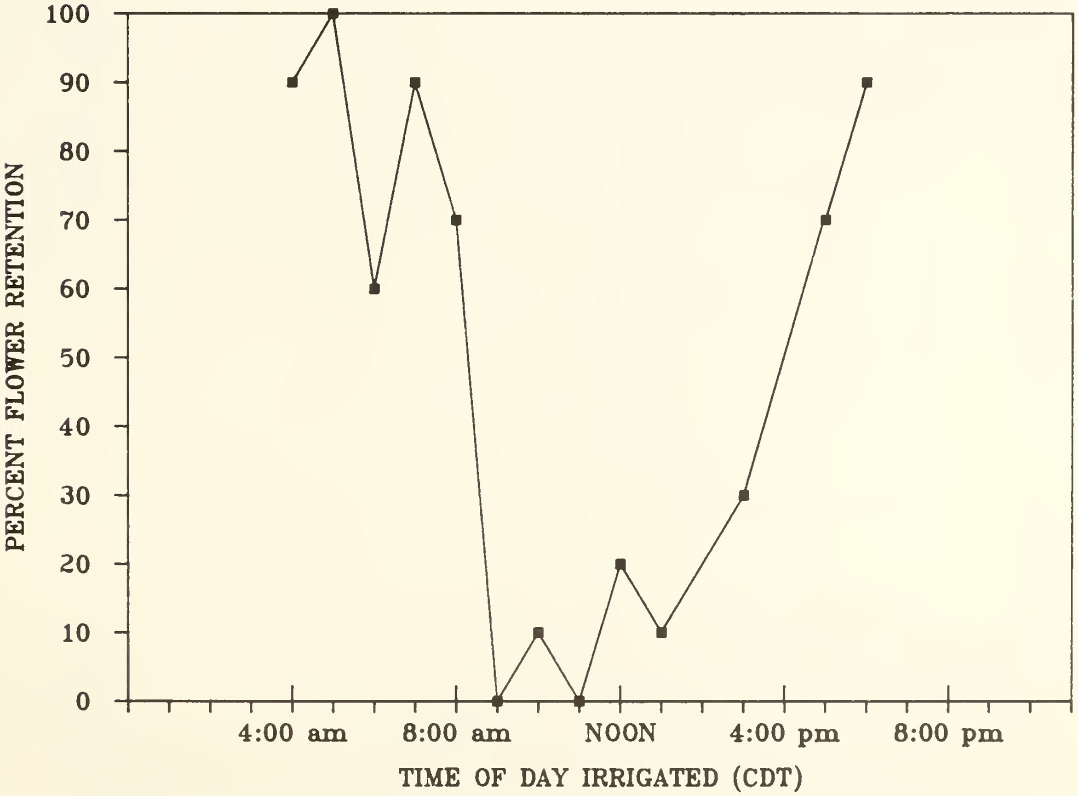

Figure 3. Most severe reduction in flower retention. Data from Belzoni, 1985.

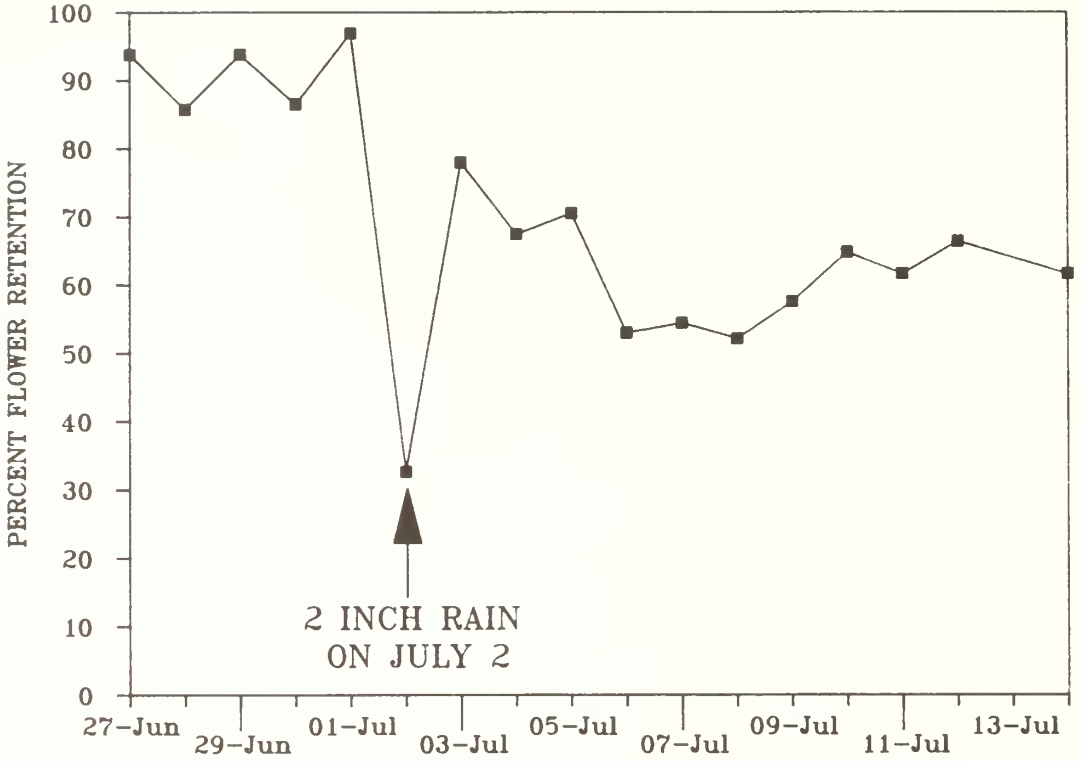

Figure 4. Influence of natural rainfall on flower retention.

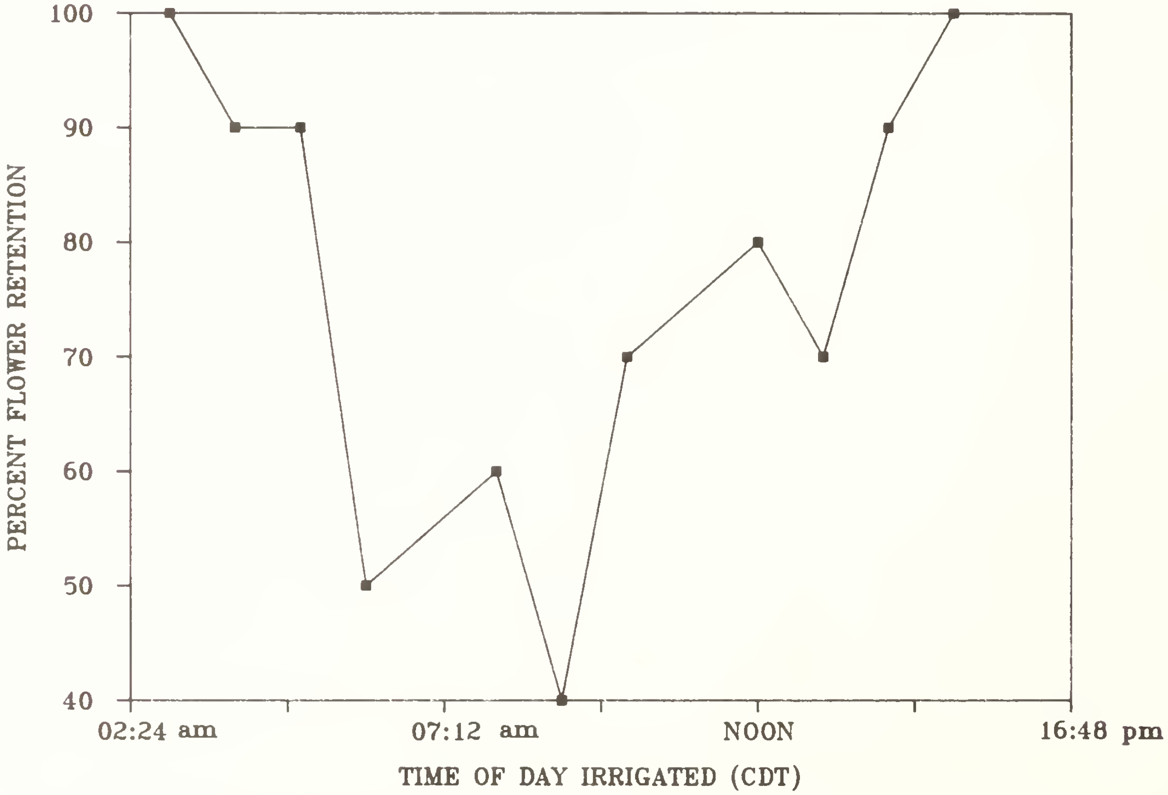

Figure 5. Changes in flower retention due to time of day of sprinkler irrigation on open cotton flowers. Data from Sumner, 1986.

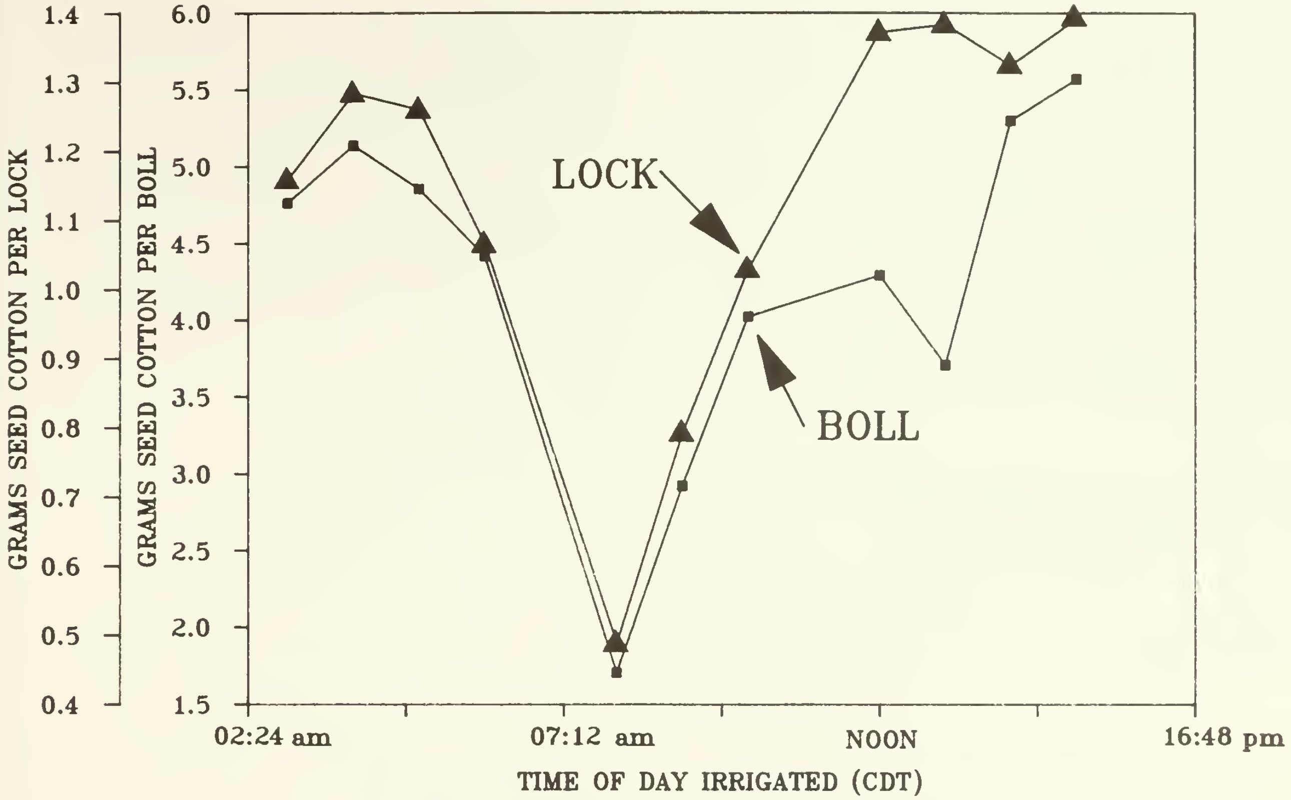

Figure 6. Influence of time of day of sprinkler irrigation on weight of seed cotton per boll and lock. Data from Sumner, 1986.

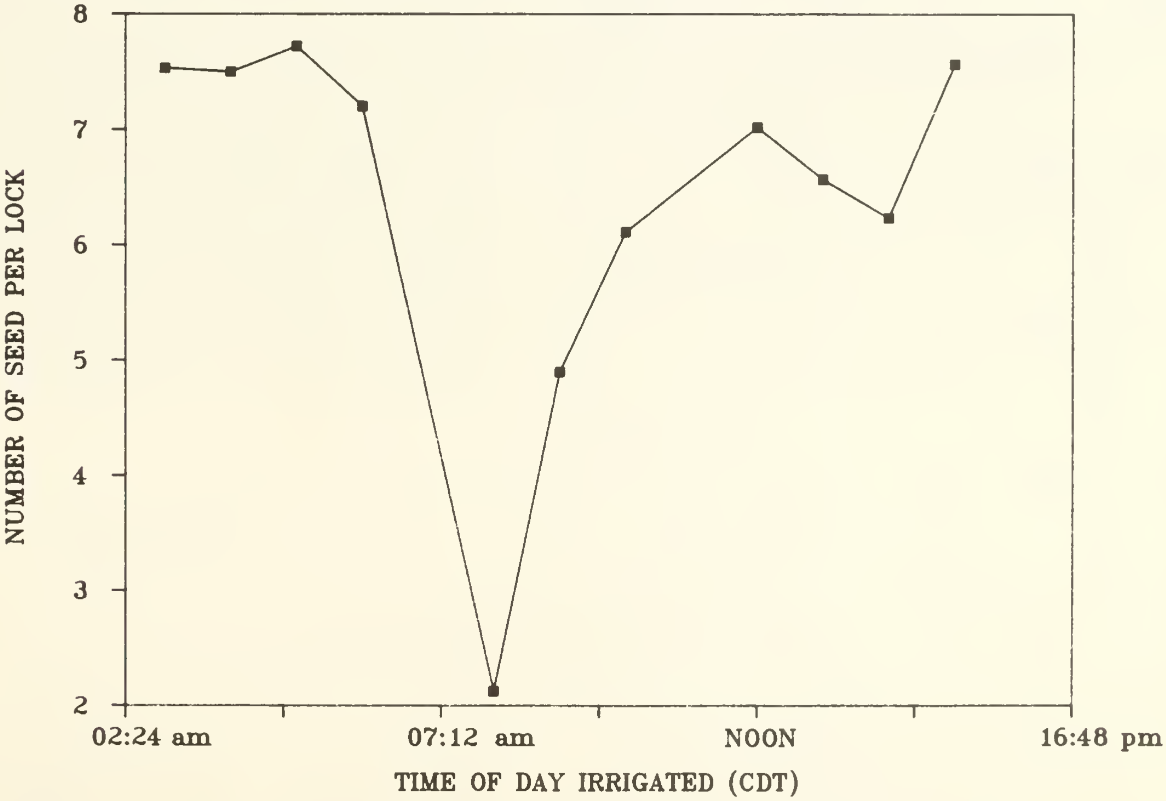

Figure 7. Influence of time of day of sprinkler irrigation on the number of seeds per lock of cotton. Data from Sumner, 1986.

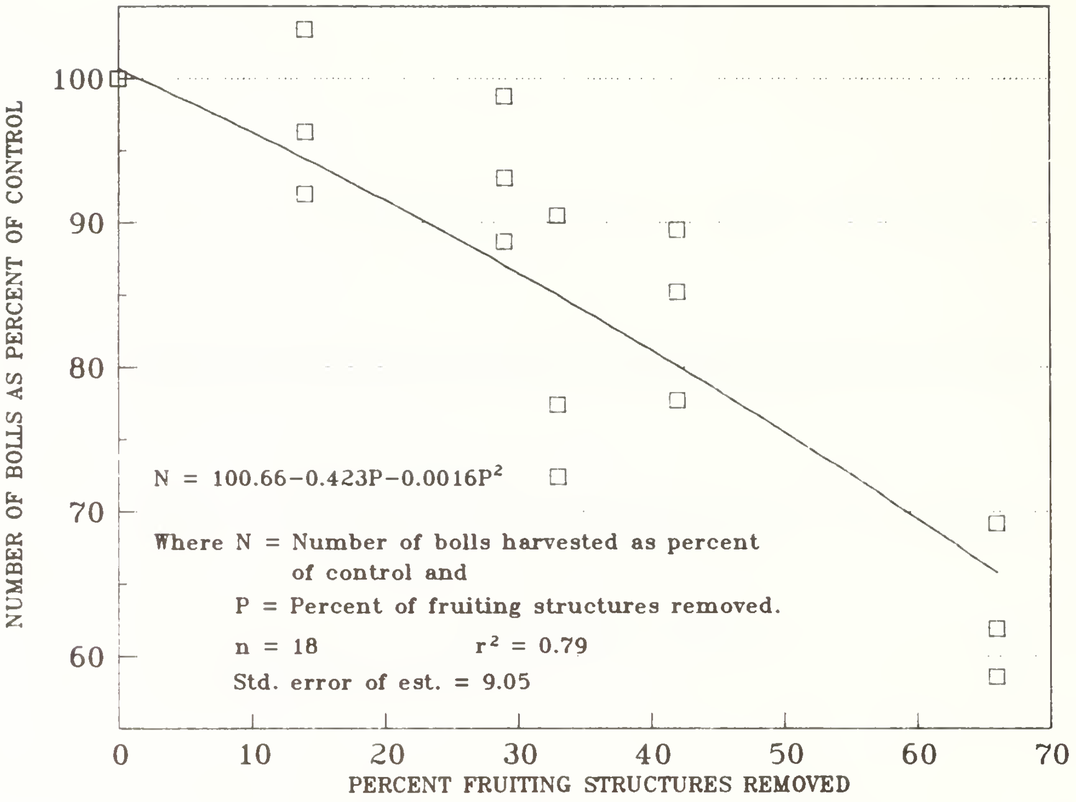

Figure 8. Average total number of bolls as percent of control for each treatment.

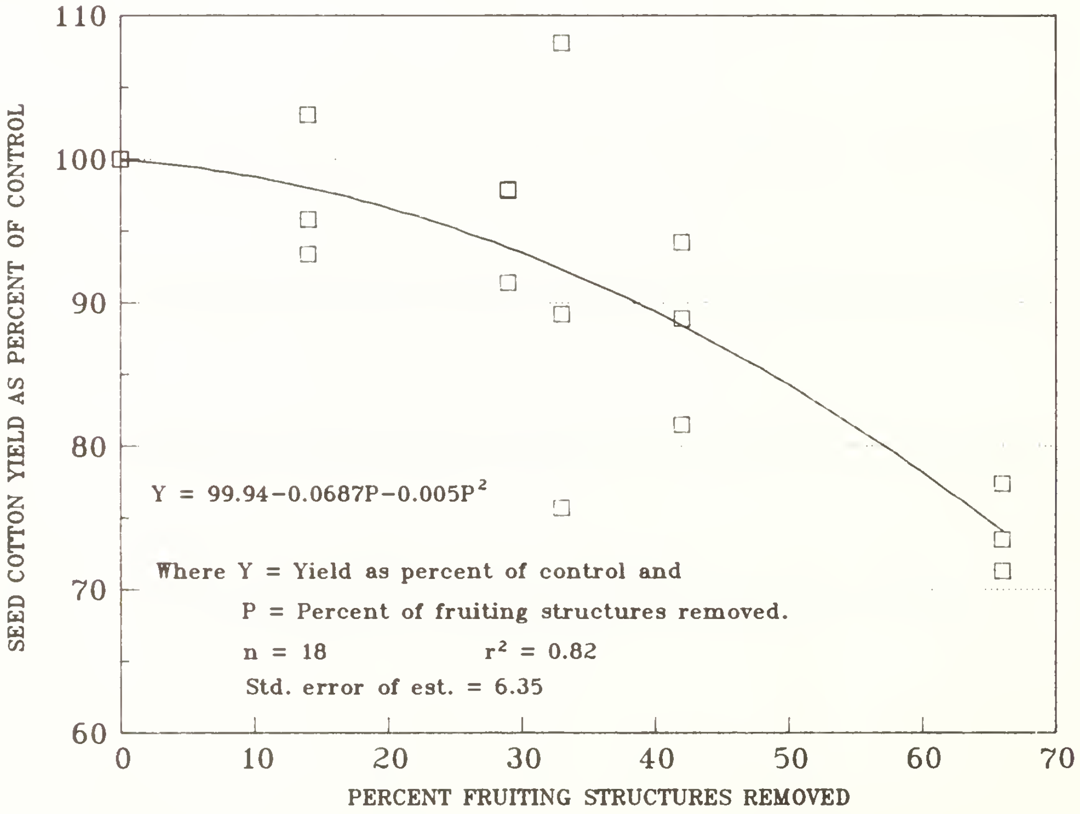

Figure 9. Average seed cotton yield at percent of control for each treatment.

from all seven experiments followed this general pattern with some differences in actual percent retention. In one notable experiment, conducted in 1985 (Figure 3), flower retention dropped to zero when sprinkler irrigation water was applied to open cotton flowers during the late morning hours.

Rainfall effects on flower retention can be seen in Figure 4. Rain on July 2, part of which fell in the morning, caused a sharp, one-day decrease in flower retention. Flowers that opened on the day of the rain had a lower retention than those flowers opening on the nonrain days.

Flower retention by time of day wetted for the 1986 test at Sumner is given in Figure 5. The tagged bolls that remained on the plants were individually hand harvested at the end of the growing season. The retention at this location is similar to other experiments. The weights of seed cotton per boll and per lock from these individually harvested bolls are given in Figure 6. Data from Leland in 1985 gave similar boll seed cotton weight reductions. Seed cotton per boll and lock was reduced with water application in the morning. In addition to reducing retention of open flowers, watering in the morning reduces the size of the retained bolls by decreasing the number of seeds in each lock (Figure 7). The daily patterns of flower retention, boll seed cotton weights, and seed numbers all suggest that water on the open flowers ruptures pollen grains and interferes with subsequent pollination of the flower (Miravalle, 1965; Stewart, 1986). Also, Pearson (1949) concluded that natural rainfall early in the day interfers with pollination and causes more ovules to form motes instead of developing into seed.

These data show a definite effect of sprinkler irrigation and rainfall on open white cotton flower retention but only suggest that there may be an effect on yields. Cotton is noted for its ability to compensate for lost fruiting structures with little or no yield loss.

Separate experiments were conducted to estimate the potential effect of flower loss on yields. The results from that work follow.

(B) Effect of Fruiting Structure Removal on Cotton Yields

Yield data from the two greenhouse experiments and field experiment 1 are reported in the same tables and data from field experiments 2, 3, and 4 are reported in other tables because of difference in percent of fruiting structures removed and different harvest schedules. Data are combined within each of the two above groups of experiments to give a treatment averaged of each yield parameter reported. Figures 8 and 9 show trends in number of harvested bolls and weight of seed cotton with changing percentage of fruiting structure removal and corresponding quadratic regression results. Data will be discussed by yield parameter.

Number of bolls harvested

As the percentage of fruiting structures removed increased, the number of harvested bolls decreased (Figure 8). The data in Tables 1 and 2 indicate that the characteristic of decreased number of bolls with increased percent fruiting structure removal was most pronounced in the earliest of the sequential harvests. This trend either decreased or reversed by the final harvests.

The increased number of bolls harvested later in the season show that cotton can compensate for fruiting structures lost during early flowering. These later set bolls did not completely compensate for the lost yield potential resulting from earlier fruit losses. Also, there was a trend toward larger bolls as the number of bolls harvested decreased (data are not given).

Table 1. Number of bolls harvested per plant from plants with varying

Percent fruiting structure removed	Sequential harvest dates 1*	2	Totals	Percent of control
	---------- Bolls per plant ----------			
Greenhouse Experiment 1				
0	29.0 a**	--	29.0	100.0
33	21.0 b	--	21.0	72.4
66	17.0 c	--	17.0	58.6
LSD	3.0	--		
Greenhouse Experiment 2				
0	11.0 a	10.0	21.0	100.0
33	8.0 b	11.0	19.0	90.5
66	5.0 c	8.0	13.0	61.9
LSD	1.0	NS		
Field Experiment 1				
0	11.0 a	2.0 a	13.0	100.0
33	7.0 b	2.0 a	9.0	69.2
66	5.0 b	4.0 b	9.0	69.2
LSD	3.0	2.0		
Average of Greenhouse Experiments and Field Experiment 1				
0	--	--	21.0	100.0
33	--	--	16.3	77.4
66	--	--	13.0	63.3

* Harvest dates: 1 = 145, 117, and 148 days after planting (DAP) for Greenhouse Experiments 1 and 2 and Field Experiment 1, respectively; 2 = 140 and 175 DAP for Greenhouse Experiment 2 and Field Experiment 1.

** Data followed by same letter are not significantly different based on LSD at the $\alpha = 0.05$. No lettering equals no significant differences within a comparison.

Lint yields

Yield differences between treatments with in an experiment were often not statistically different (Tables 3 and 4) but a trend is visible when treatments are compared collectively across all experiments (Figure 9). Lint yields decreased as fruiting structure removal increased. Loss of all flowers two and three times a week (a situation possible with common irrigation practices in the Midsouth with center privot irrigation) resulted in 4.3 and 11.8 percent, respectively, lint yield reductions (Table 4). Seed cotton yields (data are not given) showed a very similar yield trend because lint percent was not affected by the treatments.

The loss of any fruiting structures caused some loss in yield potential that was not completely compensated for by later developing fruit. The effect of fruiting structure removal on yield was the same for the removal of squares or open flowers. The extent of this yield reduction in terms of production field yields is discussed in the final section of this bulletin.

Earliness

Lint yields for each sequential harvest date from field experiments 2, 3, and 4 are given in Table 4 and Figures 10, 11, and 12. The trends in these figures show that the removal of flowers resulted in a slight delay in maturity. Removal of flowers once a week delayed the date that 60% of the lint was open by 1 day for field experiments 2 and 4. Flower removal 2 and 3 times a week delayed the 60% open date by about 2 days. Field experiment 3 was particularly early because of a water stress earlier in the season which caused shedding of many later developing squares.

In addition to a decreased yield with flower removal, there was a slight delay in maturity.

Table 2. Number of bolls harvested from 0.001 acre plots from plants with varying percentages of fruiting structures removed.

Percent fruiting structures removed	Sequential harvest dates					Totals	Percent of control
	1*	2	3	4	5		
	Number of Bolls Harvested						
Field Experiment 2							
0	28.5	151.5 a**	89.3 ab	15.8 b	15.2 b	300.3 ab	100.0
14	30.0	144.0 ab	96.2 a	24.7 a	15.5 b	310.4 a	103.4
29	19.7	129.0 bc	94.7 a	27.7 a	25.5 a	296.6 ab	98.8
42	22.8	117.5 c	76.2 b	26.7 a	25.5 a	268.7 b	89.5
LSD	NS	21.5	14.4	7.0	9.1	34.7	
Field Experiment 3							
0	130.3	70.7	9.2	5.8	--	216.0	100.0
14	124.2	71.7	8.0	4.2	--	208.1	96.3
29	129.8	61.0	6.4	4.0	--	201.2	93.1
42	102.3	52.3	6.5	6.8	--	167.9	77.7
LSD	NS	NS	NS	NS	--	NS	
Field Experiment 4							
0	38.8 a	60.7	83.8 a	130.3	--	313.6 a	100.0
14	36.2 ab	49.3	72.3 b	130.8	--	288.6 ab	92.0
29	31.3 ab	52.8	65.8 b	128.2	--	278.1 b	88.7
42	26.8 b	49.3	67.5 b	123.7	--	267.3 b	85.2
LSD	11.9	NS	11.3	NS	--	29.3	
Averages—Field Experiments 2, 3, and 4							
0	--	--	--	--	--	276.6 a	100.0
14	--	--	--	--	--	269.0 a	97.2
29	--	--	--	--	--	258.6 a	93.5
42	--	--	--	--	--	234.6 b	84.1
LSD	--	--	--	--	--	18.4	

* Harvest dates: Field Experiment 2 were Aug. 22, Sept. 3, 11, 18, and 29. Field Experiment 3 were Aug. 29, Sept. 11 and 18, and Oct. 1. Field Experiment 4 were Aug. 25, Sept. 3 and 11, and Oct. 1.

** Data followed by same letter are not significantly different based on LSD at the $\alpha = 0.05$. No lettering equals no significant differences within a comparison.

Table 3. Lint yields per plant from plants with varying percentages of fruiting structures removed.

Percent fruiting structure removed	Sequential harvest dates		Average	Percent of control
	1*	2		
	------ Grams lint per plant ------			
Greenhouse Experiment 1				
0	34.2 a	--	34.2	100.0
33	30.5 a	--	30.5	89.2
66	24.4 b	--	24.4	71.3
LSD	5.7	--		
Greenhouse Experiment 2				
0	18.5 a	17.4	35.9	100.0
33	15.6 a	23.2	38.8	108.1
66	9.4 b	17.0	26.4	73.5
LSD	5.0	NS		
Field Experiment 1				
0	19.8 a	3.7	23.5	100.0
33	14.3 a	3.5	17.8	75.7
66	10.6 b	7.6	18.2	77.4
LSD	5.9	NS		
Average of Greenhouse Experiments and Field Experiment 1				
0	--	--	31.2	100.0
33	--	--	29.0	91.0
66	--	--	23.0	74.1

* Harvest dates: 1 = 145, 117, and 148 days after planting (DAP) for Greenhouse Experiments 1 and 2 and Field Experiment 1, respectively; 2 = 140 and 175 DAP for Greenhouse Experiment 2 and Field Experiment 1.

** Data followed by same letter are not significantly different based on LSD at the $\alpha = 0.05$. No lettering equals no significant differences within a comparison.

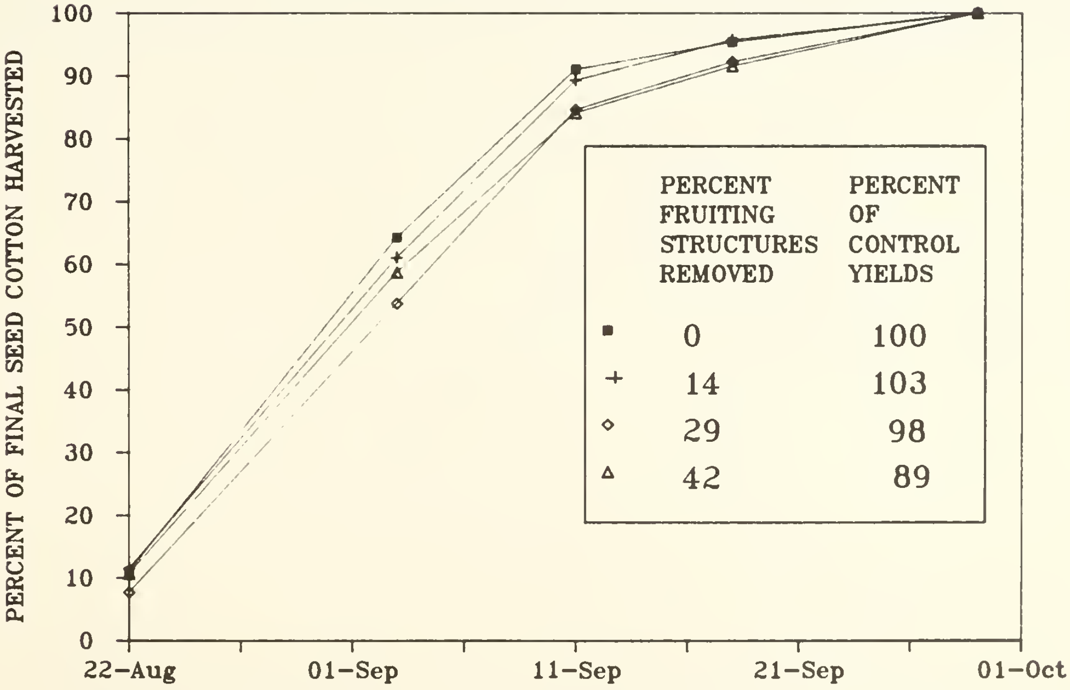

Figure 10. Percent of final seed cotton yields harvested at different dates and final seed cotton yields as percentage of controls. Field experiment 2.

Table 4. Lint yields harvested from 0.001-acre plots from plants with varying percentages of fruiting structures removed.

Percent fruiting structures removed	Sequential harvest dates					Totals	Percent of control
	1*	2	3	4	5		
	Grams lint per plot						
Field Experiment 2							
0	43.7	211.6 a	106.4 ab	17.2 b	18.4 ab	397.3 ab	100.0
14	47.0	203.2 ab	115.5 a	26.1 a	17.7 b	409.5 a	103.1
29	30.0	179.0 ab	120.0 a	29.5 a	29.9 a	388.4 ab	97.8
42	37.7	169.6 b	89.6 b	26.5 a	29.8 ab	353.3 b	88.9
LSD	NS	36.8	18.7	8.1	12.1	54.0	
Field Experiment 3							
0	222.0	73.1	8.8	3.1	--	307.1	100.0
14	212.9	71.3	7.4	2.5	--	294.1	95.8
29	225.0	65.7	7.1	2.7	--	300.5	97.9
42	180.3	58.8	6.1	5.0	--	250.2	81.5
LSD	NS	NS	NS	NS	--	NS	
Field Experiment 4							
0	57.0	66.3	98.4 a	143.5	--	365.2	100.0
14	53.6	58.9	82.8 ab	145.6	--	340.9	93.4
29	47.7	59.4	81.1 b	145.7	--	333.8	91.4
42	42.9	61.5	82.7 ab	156.9	--	344.0	94.2
LSD	NS	NS	15.8	NS	--	NS	
Averages--Field Experiments 2, 3, and 4							
0	--	--	--	--	--	356.5 a	100.0
14	--	--	--	--	--	348.2 ab	97.4
29	--	--	--	--	--	340.9 ab	95.7
42	--	--	--	--	--	315.8 b	88.2
LSD	--	--	--	--	--	36.7	

---

* Harvest dates: Field Experiment 2 were Aug. 22, Sept. 3, 11, 18, and 29. Field Experiment 3 were Aug. 29, Sept. 11 and 18, and Oct. 1. Field Experiment 4 were Aug. 25, Sept. 3 and 11, and Oct. 1.

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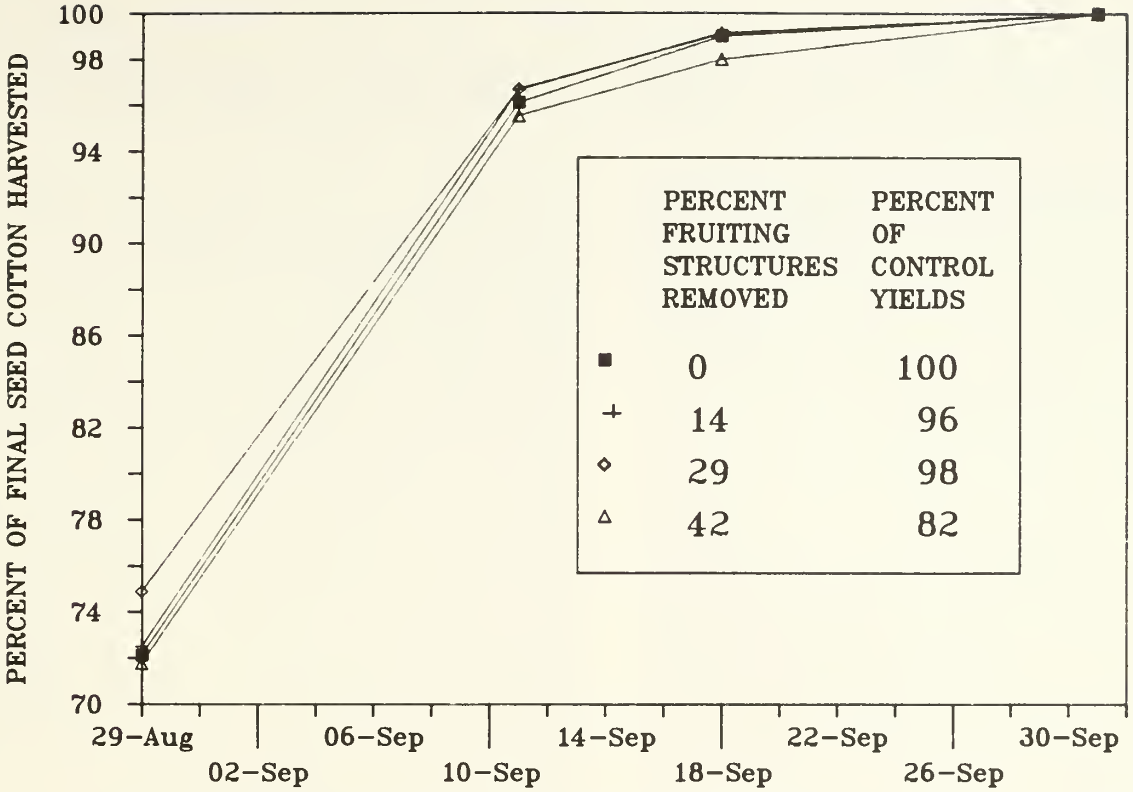

Figure 11. Percent of final seed cotton yields harvested at different dates and final seed cotton yields as a percentage of controls. Field experiment 3.

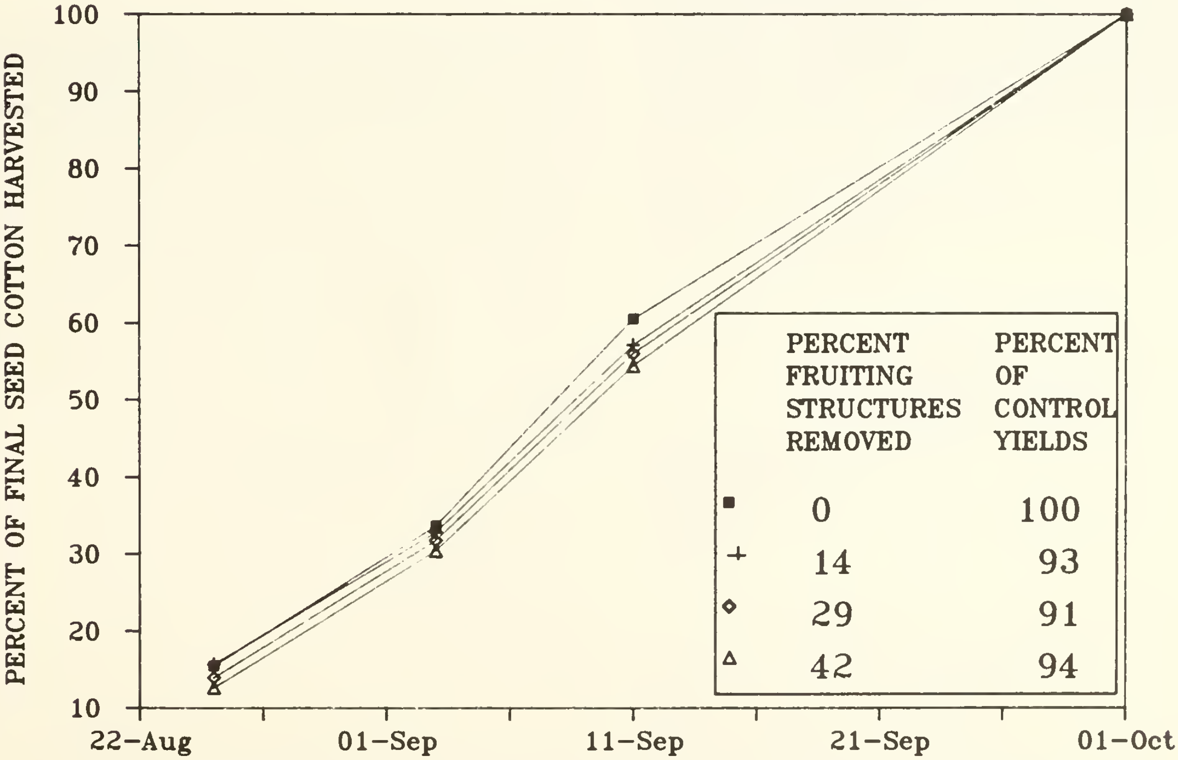

Figure 12. Percent of final seed cotton yields harvested at different dates and final seed cotton yields as a percentage of controls. Field experiment 4.

Projected Yield Reductions in Production Fields Due to Increased Shed of Flowers Caused by Sprinkler Irrigation on Open Flowers

Information in the first two sections of this bulletin show that (1) flower retention is reduced when sprinkler irrigation or rainwater is applied to open cotton flowers particularly during the morning, and (2) fruiting structure removal approximating flower losses caused by sprinkler irrigations can reduce yields. The yield reductions measured on small plots may not be directly comparable to yield losses in commercial production fields. The yields obtained in fruiting structure removal experiments simulate an extreme case where a large portion of flowers are lost repeatedly on the same area of a field. This does not simulate the real world of center pivot irrigation in production fields. Usually, all white, open flowers are not lost due to sprinkler irrigation (Figure 2) and the same portion of a field need not be watered at the same time of day with each irrigation. The small plot yield data can be applied to production fields in the following fashion.

Calculating Production Field Yield Reductions

Assume the following conditions: Water is applied twice a week to flowering cotton with a center pivot irrigation system that operates 24 hours a day. All of the white open flowers that receive the sprinkler water application from 8:00 a.m. to 2:00 p.m. (6 hours) are lost. The same part of the field is watered during the morning on every irrigation throughout the season. The average yield reductions measured in experimental plots with all flowers removed two times (treatment 2, field experiments 2, 3, and 4) a week (95.7% of yield potential) are experienced on the part of the field watered in the morning. The rest of the field yields at full (100%) potential since there is no loss of yield potential due to increased flower abortion.

The portion of the field watered form 2:00 p.m. to 8:00 a.m. is three-fourths of the total area of the field watered each day (18 hours out of 24) and this part of the field will yield full potential, i.e., 100 percent (see the wagon wheel effect in Figure 13). The part of the field watered from 8:00 a.m. to 2:00 p.m. is one-fourth of the daily portion watered (6 hours out of 24) and this area of the field will yield at just 95.7 percent of full potential because of reduced flower retention caused by the sprinkler irrigation. Calculation of the entire field yield is as follows:

(100% yield on 3/4 of field) +
(95.7% yield on 1/4 of field) = 98.9% **(1)**

Lint yield loss caused by water on open cotton flower two times a week is only 1.1 percent. Again, this represents the extreme case. The same calculation for

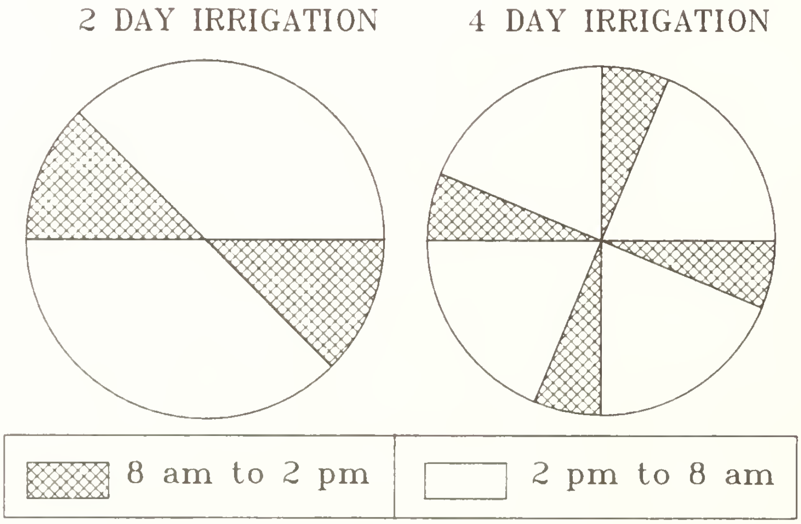

Figure 13. Areas of center pivot irrigation system covered between 8:00 a.m. and 2:00 p.m. when complete revolution of system takes 2 or 4 days. Shaded areas in both cases are 25 percent of the field.

irrigation 1 and 3 times a week will be, again using data from Table 4:

One irrigation a week:

$$\text{(100\% yield on 3/4 of field)} + \text{(97.5\% yield on 1/4 of field)} = 99.4\% \quad (2)$$

Three irrigations a week:

$$\text{(100\% yield on 3/4 of field)} + \text{(88.2\% yield on 1/4 of field)} = 97.0\% \quad (3)$$

These yield losses from sprinkler irrigation on open cotton flowers could be reduced or eliminated by not watering during the morning and early afternoon. But this would require that a sprinkler be turned off about one-fourth of the time, thus reducing the effective delivery capacity of the system for any extended period of time by one-fourth. Few sprinkler systems in the Midsouth have sufficient capacity to be off one-fourth of the time and still meet the water needs of the cotton crop during dry summer months. Therefore, turning off a system to improve yields by reducing flower shed associated with morning watering could easily reduce water applications sufficiently to induce yield losses due to water deficiencies. Yield losses from 100 percent of a field caused by an insufficient supply of water could easily be much larger than any yield gained by improving flower retention and yield on the fraction of the field watered during the morning.

Minimizing Affect of Reduced Flower Retention Caused by Morning Irrigation

Staggering irrigations so that a single area of a field is not sprinkler irrigated during the morning on sequential irrigations can reduce yield losses in some cases. For this explanation, assume the same field conditions as used in the proceeding section. Irrigating once a week in the morning and early afternoon over the same location can reduce whole field yields by 0.6 percent (Equation 2, 100 − 99.4 = 0.6). Irrigating twice a week in the morning and early afternoon can reduce whole field yields by 1.1 percent (Equation 1, 100 – 98.9 = 1.1). Staggering two irrigations to cover different areas of a field will double the area irrigated in the morning and early afternoon but the field loss on that larger area will be only 0.6 percent, that yield was experienced by once a week irrigation. The net effect on yield is very small because the area experiencing decreased flower retention is doubled and the yield decrease experienced is approximately halved from 1.1 percent to 0.6 percent.

It is possible to stagger irrigations such that an area of the field would be irrigated from 8:00 a.m. to 2:00 p.m. (6 hours or one-fourth of day) once each four irrigations or once every 2 weeks with two irrigations a week. This may eliminate the effect of reduced flower retention on yield but no information is available to support or reject this option.

When sprinkler irrigations are made three times a week, some gains can be made by staggering irrigations. The total losses from irrigating one or two times a week from 8:00 a.m. to 2:00 p.m. on a larger portion of the field are less than the losses from three irrigations a week over the same area from 8:00 a.m. to 2:00 p.m.

It may be possible to avoid or substantially reduce this problem by not watering during the mornings only during the first 10 to 15 days of flowering and watering throughout the day the rest of the season. This is probably the best solution for the following reasons.

Percent retention of blooming cotton flowers is highest early in flowering and is lowest after peak bloom. Not watering in the morning during early flowering will allow the plants to keep most of the fruit setting at that time. This will help assure an early boll load. This high boll retention period occurs when plants are still small, resulting in a daily water use that is less than needed when plants are near full size. Irrigation systems are designed to meet the water requirements during the highest demand period. With the smaller water demand during early flowering, it should be possible to turn a system off for one-fourth of the day and still meet the crop water requirements. Late in the bloom period, flower retention is usually naturally low if early boll set has been good. Watering during the morning at this time will still reduce boll retention but since retention is low at this stage of development, the total loss of bolls is very small. Crop water demand is highest late in flowering and at this time it would not be advisable to turn a system off in the mornings.

Conclusions from Research

(1) Applying sprinkler irrigation water to white open cotton flowers reduces retention of those flowers. This effect is most severe during the early morning, just as flowers are opening. Rainfall has a similar effect.

(2) Flower losses similar to those induced by sprinkler irrigation can reduce experimental plot yields by 5 to 13 percent with a 1 to 2-day delay in maturity (60% open).

(3) Calculations based on research results indicate that the effect of flower loss from sprinkler irrigation on yields of production fields is 3 percent or less and could be easily be held to less than 1 percent.

Suggestions for Producton

(1) Do not turn off sprinkler irrigation systems during morning hours if there is any concern about maintaining an adequate supply of water to the crop.

(2) It may be acceptable to avoid irrigation during morning hours in the first 10 days of flowering when boll retention is high and water demands are still moderate because of the small canopy size.

(3) If a system must be turned off for maintenance or other unavoidable reasons, shut down during the morning.

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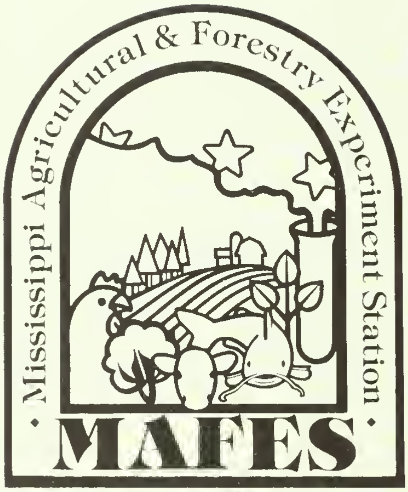
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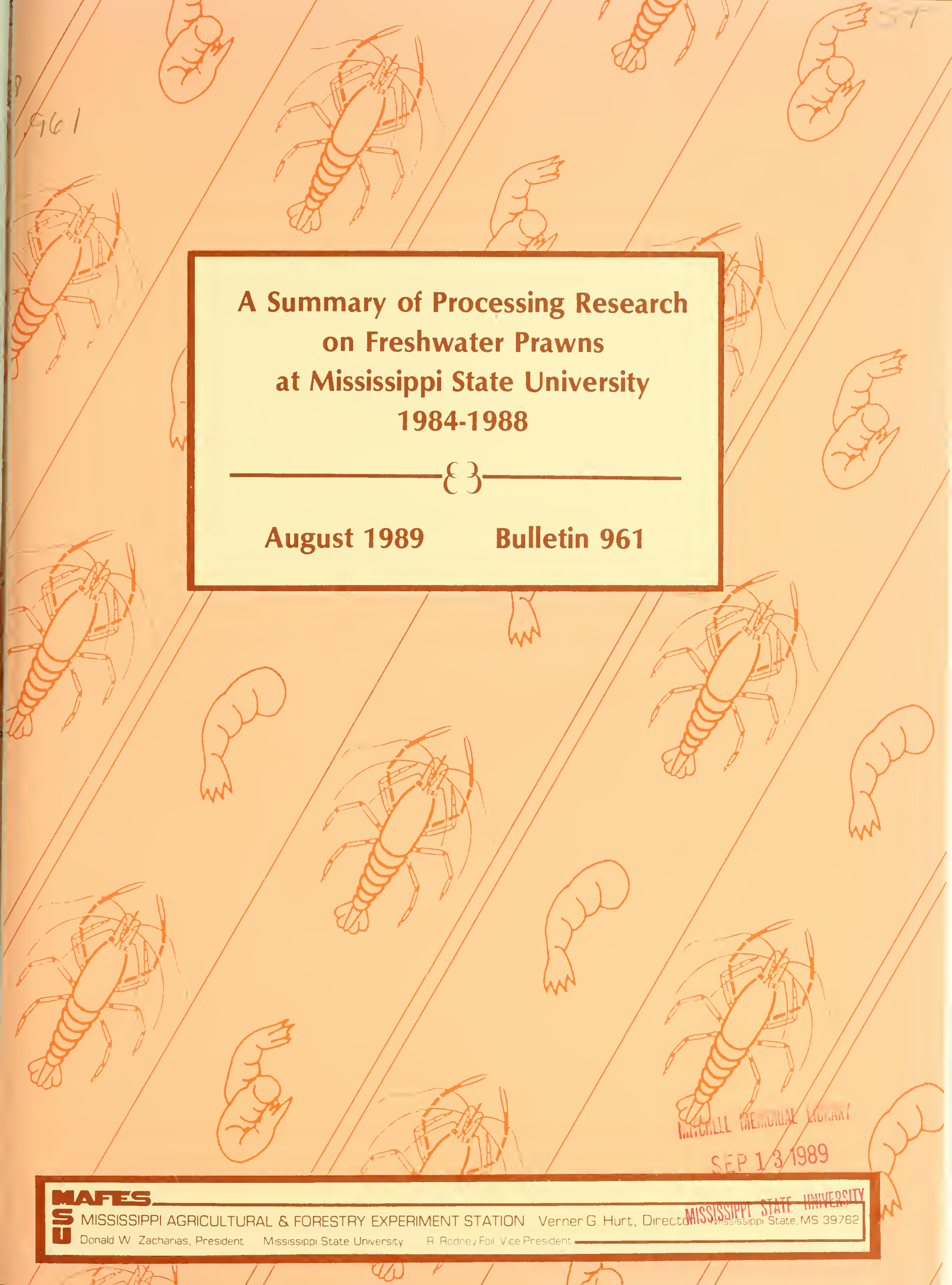

A Summary of Processing Research on Freshwater Prawns at Mississippi State University 1984-1988

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A Summary of Processing Research on Freshwater Prawns at Mississippi State University

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Table of Contents

Chapter **Page**

Acknowledgments ii

Contributors iv

I. Introduction 1

II. Composition 3

III. Time-motion studies on processing freshwater prawns 6

IV. Prediction of tail and meat weight of freshwater prawns 7

V. Preservation of freshwater prawns under refrigerated and iced conditions 9

VI. Effect of precooking, packaging, and storage temperature on shelf-life of frozen deheaded prawns 12

VII. Effect of form of prawn and precooking on shelf-life of prawns 15

VIII. The effect of prawn form, ice-holding, and thawing time on the texture and shelf-life of prawns 17

References 19

Chapter I

Introduction

J. L. Silva, J. O. Hearnsberger, and G. R. Ammerman

The temperate zones of the United States have the potential to capitalize on the technology and consumer demand for freshwater prawns (*Macrobrachium rosenbergii*) (Wellborn, 1985). Studies on the production (Bauer et al., 1976; Liao and Smith, 1983) of the prawns have shown some economic potential, especially if the pond and associated facilities are already available. Studies have also shown that prawns are very acceptable to the restaurant trade (Dillard et al., 1986) and the retail market. Freshwater prawns, placed in the ponds after the cold season has ended, must be seasonally harvested before the temperature of the water drops below 64°F (18°C) (Smith et al., 1978). It is this seasonality that makes the freezing preservation necessary to keep a year-round supply.

Information on the frozen storage stability of freshwater prawns showed early deterioration in texture when the prawns were stored whole (Hale and Waters, 1981). A significant decrease in the organoleptic texture quality of whole frozen prawns after 6 months of storage was reported by Miyajima and Cobb (1977). Nip and Moy (1979) noted significant textural changes in whole frozen prawns after one month of frozen storage, but found no significant differences in other organoleptic parameters. Deheaded, frozen prawns had a consistently firmer texture than the whole prawns (Hale and Waters, 1981).

Deheaded prawns were reported by Angel et al. (1981) to be composed of 79.3% moisture, 17.5% crude protein, 1.9% fat, and 1.3% ash. Moreover, an apparent increase in moisture with a decrease in crude protein were found after 14 days of storage at 0°C. Sidwell et al. (1974) found that the edible portion of deheaded prawns contained 75.3% moisture, 16.8% protein, 1.2% fat, and 2.7% ash.

Chilled-killed prawns in ice ready to be processed.

Reddy et al. (1981) reported that prawns contained approximately 1.6% fat, which is composed of 23% saturated, 46% monounsaturated, and 31% polyunsaturated fatty acids.

Chanmugam et al. (1983), however, reported that freshwater prawns contained about 3.2% fat, consisting of 35.8% saturated, 35.2% monounsaturated, and 29.0% polyunsaturated fatty acids. There was no complete information on the feed type or morphology of the prawns in these studies, and this may account for the differences in the composition of the fatty acids.

Although the fat is mostly unsaturated, freshwater prawns are stable to oxidative rancidity because the 2-thiobarbituric acid (TBA) values reported by Reddy et al. (1981) for frozen prawns held for 12 months did not exceed 3.0, a minimum TBA value associated with rancidity in seafood. Angel et al. (1981) reported TBA values between 0.25 and 0.66 for frozen prawns held at 0°C (32°F) for up to 14 days.

Baranowski et al. (1984) suggested that the enzyme system in the prawns contains a collagenolytic portion believed to be responsible for the breakdown of tail muscle texture. A report by Nip et al. (1985) showed that the addition of a collagenolytic enzyme fraction to prawn tissue increased the hydrolysis of prawn collagen.

Because the literature is conflicting with respect to the composition and freezing stability of freshwater prawns, food technologists at Mississippi State University studied the processing yield, chemical composition, freezing stability, chemical and physical changes, and organoleptic acceptability of the prawns as affected by various processing variables.

This bulletin is a summary of data accumulated from 4 years of research in the processing and storage of freshwater prawns raised in Mississippi. The reader is encouraged to contact the authors for additional information.

The prawns used for the studies reported in this bulletin were reared at the Mississippi Agricultural and Forestry Experiment Station (MAFES) Aquaculture Unit located on the Mississippi State University Animal Research Center near Starkville. The prawns were stocked at densities of 16,000 to 48,000 per acre in 0.15-acre to 0.17-acre ponds. They were fed a 25% crude protein, pelleted, sinking feed at a rate of 20% of body weight in the early growth stages, reducing to a rate of 3% of body weight prior to harvesting (D'Abramo et al., 1986; 1988). The ponds were stocked in early May with nursed juveniles, ranging in weight from 0.17 gram to 0.75 gram. Prawns were harvested in late September or early October and ranged in weight from 30 grams to 50 grams.

Chapter II

Composition of Freshwater Prawns

J. L. Silva, J. O. Hearnsberger, G. R. Ammerman,
W. E. Poe, R. P. Wilson, G. Leigeber, and R. Wander

The literature is conflicting when reporting the composition of freshwater prawns (USDA, 1963; Sidwell et al., 1974). The reported fat content of prawn tissue ranged from 1.2% to 1.9% or higher (Sidwell et al., 1974; Angel et al., 1981). Additionally, the fatty acid composition, which gives a measure of the degree of saturation of lipids, is known to be influenced by the feed, age, and morphology of the prawns and by environmental conditions. Though very low in fat, the cholesterol content of the prawns is of interest to both researchers and consumers. Free amino acids have been reported to give an indication of the enzyme activity in prawns. Iodine content of a sample of prawns is also of concern since allergic reactions to iodine in shellfish are known to occur in humans.

Materials and Methods

Materials

Chill-killed freshwater prawns were obtained from the Mississippi Agricultural and Forestry Experiment Station (MAFES) aquaculture research facilities. The prawns were fed diets containing 25% protein, similar to those for channel catfish (D'Abramo et al., 1986; 1988). The prawns weighed 30-50 g (1 to 2 oz.), whole weight, and were kept in ice for not longer than 12 hours before being processed and stored frozen. Approximately 2,500 prawns were used for these studies.

Methods

Data reported in this chapter are the result of several experiments. Proximate (chemical) composition of the prawn meat was determined from prawns following the design and methods described in Chapter 7. Fatty acid profile was conducted based on designs described in Chapters 7 and 8.

Sample preparation. At zero-day and at 60-day intervals, six tails per treatment were selected at random, partially thawed, shelled, and the meat was chopped manually with knife. The chopped samples were weighed. Twenty grams of chopped meat were taken for TBA value determination and the rest were dried, as described below, to be used for other determinations.

Moisture. The moisture of the chopped sample was determined by the method described in AOAC 24.003 (1980), which specifies drying for 18 hours at 100°C (212°F). Total moisture in the sample on a wet weight basis was calculated.

Protein. The percent protein (Kjeldahl N x 6.25) was determined on a 0.7004-gram portion of the chopped, dried sample and the result was converted to a wet weight basis. The AOAC method 2.057 (1980) for total Kjeldahl N was used.

Fat. Fat was extracted from 2 grams of the chopped, dried sample by refluxing for 5 hours in ethyl ether as described by AOCS Ba 3-38 (1981). The result was converted to a wet weight basis and reported as percent fat.

Ash. The AOAC method 7.009 (1980) was used to determine ash on a 2-gram portion of the chopped, dried sample. The result was converted to a wet weight basis and reported as percent ash.

TBA value. The 2-thiobarbituric acid was determined by the distillation method described by Tarladgis et al. (1960) using a 10-gram portion of the chopped sample. The optical density of the sample was read against a blank at a wavelength of 538 nm. The O.D. reading was multiplied by the factor 7.8 to convert to milligrams of malonaldehyde per kilogram (mg/kg) of sample.

Free fatty acids. The fat extracted from the chopped, dried samples for fat determination was used to determine the percent free fatty acids. The AOCS official method Ca 5a-40 (1981) was slightly modified to determine the free fatty acids. Fifty milliliters (ml) of hot neutralized alcohol and 0.01 N NaOH were used. The percent free fatty acids of the fat was calculated and expressed as oleic acid on a whole sample basis.

Fatty acid profiles. The fat was extracted from the chopped, dried sample by the procedure of AOCS Ba 3-38 (1981). The liberated fatty acids were esterified according to AOAC methods 28.053-28.056 (1980). A boron trichloride catalyst was used rather than the boron trifluoride reagent. Hexane was replaced with isooctane for the extraction. Methyl esters of the fatty acids were separated and analyzed by the gas chromatographic methods of AOAC 28.057-28.065 (1980). Results were reported for each acid as a percent of the total fatty acids. Fatty acid profiles were performed on the headless prawns at 60, 120, and 300 days of frozen storage.

Free Amino Acids. Free amino acids were determined from each replicate of raw prawn tails stored for up to 6 months at −18°C. Prawn tails were frozen in liquid nitrogen and ground with a mortar and pestle. Approximately 1.0 gram of freshly ground tail was blended with 3.0 ml of 4% 5-sulfosalicylic acid (to precipitate any protein present) in a ground glass grinder. The solution was centrifuged and the supernatant injected onto a Beckman Model 120C (Blue Bell, PA) ion exchange amino acid analyzer. Results were reported as milligrams of free amino acid per gram (mg/g) dry tissue.

Cholesterol. Cholesterol was determined after extraction of the lipids in the prawn tissue with hexane and saponification using alcoholic potassium-hydroxide. Cholesterol was determined colorimetrically. The effects of cooking (frying and boiling), blanching, packaging, and tissue type were evaluated for compositional variations.

Iodine. The iodine content on a sample of five prawn tails (200 g) was determined by ion selective electrode analysis according to the method of Hoover et al. (1971).

Results and Discussion

The chemical composition of freshwater prawns (tissue) as influenced by different processing and storage conditions is shown in Table 2.1. Blanched prawns showed higher ($P<0.05$) protein values and higher ($P<0.05$) fat values than raw prawns. However, the differences were not of any practical significance since they were small. Packaging in vacuum bags or storage temperature did not have any effect on the composition of the prawns. Overall, the prawns contained 77.6% moisture, 19.9% protein, 0.4% fat, and 1.2% ash. Fat content for these freshwater prawns was half of that reported for marine shrimp (USDA, 1963).

Table 2.1. Effect of blanching, packaging and storage temperature on the composition of headless, frozen prawns.

Treatment	Composition (% of total weight)			
	Moisture	Protein	Fat	Ash
Blanching				
Blanched	77.4a*	20.2a	0.43a	1.21a
Not blanched	77.8a	19.6b	0.36b	1.23a
Packaging				
Vacuum	77.5a	19.9a	0.39a	1.24a
Atmosphere	77.7a	19.9a	0.40a	1.22a
Storage Temp (C)				
−23°	77.8a	19.7a	0.39a	1.22a
−18°	77.4a	20.1a	0.40a	1.22a
Overall Means	77.6a	19.9	0.40	1.22

*Means within a column in each treatment not followed by the same letter differ significantly ($P<0.05$) as determined by the F-test in the ANOVA.

Table 2.2. Changes in the fatty acid composition of headless, frozen prawns during storage at −18°C (as percent of total fatty acids).

Fatty acid	Storage time (months) 2	4	10	Overall means
	% of total fatty acids			
C14:0	0.39	–	0.24	0.21
C16:0	29.64	16.13	23.54	23.10
C16:1	2.61	–	3.20	1.94
C17:0	0.24	–	0.07	0.11
C18:0	15.61	16.48	11.00	14.36
C18:1	34.64	32.68	27.96	31.76
C18:2 + 19:0	14.56	26.54	15.02	18.71
C18:3	0.80	–	1.76	0.85
C20:1	–	8.17	0.22	2.80
C20:2	–	–	0.18	0.06
C20:3	0.33	–	–	0.11
C20:4	0.51	–	6.32	2.28
C21:0	0.20	–	–	0.07
C22:1	–	–	7.33	2.44
SFA[1]	46.08	32.61	34.85	37.85
MUFA[2]	37.25	40.85	38.71	38.94
PUFA[3]	36.67	26.54	36.44	26.44

[1] Saturated fatty acids.

[2] Monounsaturated fatty acids.

[3] Polyunsaturated fatty acids.

Fatty acid composition of prawn tissue, as affected by storage time at −18°C, is shown in Table 2.2. Fatty acids varied during storage time, but no clear trend was noticed. Overall, oleic (C18:1), palmitic (C16:0), linoleic (C18:2), and stearic (C18:0) acids were the fatty acids present in largest quantities. These four fatty acids constituted approximately 88% of the total fatty acids in the prawns. Of the total fatty acids present, 37.9% were saturated, 38.9% monounsaturated, and 26.4% polyunsaturated. The fatty acid composition may be affected by the type of feed, sex, age, and/or size of the animals as well as by environmental conditions (Silva-Pacheco, 1986).

The free amino acid profile for freshwater prawn tissue, as affected by time of storage at −18°C, is shown in Table 2.3. There was an increase of 24.8 mg/g of dry weight in the total amount of free amino acids in prawn tissue after 2 months of frozen storage. However, there were no changes in the total amino acids after 6 months of frozen storage.

Glycine, proline, alanine, lysine, and serine content increased considerably throughout storage. Glycine has been reported as one of the major components in collagen tissue and a factor in the formation and stability of the collagen triple helical structure (Matthews, 1975). Proline and alanine are also found in collagen of muscle tissue (Nip et al., 1981). The action of proteolytic enzymes found in the digestive tract (hepatopancreas) has been suggested to affect the texture and free amino acid content of prawn tissue (Baranowski et al., 1984). The action of a collagenolytic enzyme fraction on chilled stored prawns was suggested as a possible cause for mushiness in prawns (Nip et al., 1985).

Ammonia levels increased by the end of 2 months of frozen storage and remained at the same level thereafter. However, these ammonia levels are lower than those reported for spoiled white shrimp (*Penaeus setiterus*) under iced storage (Cobb et al., 1974).

The cholesterol content of freshwater prawns, as affected by type of tissue (tail tissue or whole body tissue), blanching (3 minutes at 100°C), and cooking method (raw, boiled for 8 minutes, and fried at 190°C until done) are shown in Table 2.4.(Leigeber, 1987). There was a higher ($P<0.05$) cholesterol content in the tissue from the tails than in the whole tissue of prawns. Blanching did not affect the cholesterol content of the prawns but cooking did ($P<0.05$). Boiled prawns contained more cholesterol than raw prawns (tail tissue); fried prawn tails contained the most. However, cholesterol on a dried basis was not affected by cooking method. These differences in cholesterol were probably caused by dehydration of the tissue during cooking.

Data reported by Hearnsberger (1987) showed the cholesterol content of prawn tail tissue to be 98.4 to 70.6 mg/100g of tissue. The cholesterol of marine shrimp was reported to be 125 mg/100 g (USDA, 1963) to 159 mg/100 g of tissue (Sidwell et al., 1974). The cholesterol content may depend on several factors such as diet, size of animal and environmental conditions, thus the conflicting data.

Iodine values were reported to be 0.14 ppm for prawn tissue (Hearnsberger, 1987). The iodine content of medium prawns (30 g whole weight) was found to be 0.14 ppm (Hearnsberger, 1987), which is below the average of 0.80 ppm for shellfish and 0.83 ppm for marine fish (Shils and Young, 1988).

Table 2.4. Cholesterol content of freshwater prawns as affected by type of tissue, blanching, and cooking method.

	Cholesterol (mg/100 g of tissue)	
Treatment	**Wet basis[1]**	**Dry basis[2]**
Tissue type		
Whole	154a*	636a
Tail	172b	763b
Blanching		
Control	159a	684a
Blanched	167a	715a
Cooking		
Raw	169a	798a
Boiled	232b	837a
Fried	334c	694a

[1] mg of cholesterol per 100 g of tissue.

[2] mg of cholesterol per 100 g of dry tissue.

* Means within treatment, in a column not followed by the same letter differ significantly ($P<0.05$) as determined by the LSD.

Table 2.3. Mean free amino acids in freshwater prawns by storage time at –18°C.

Amino Acid	Storage time (months)		
	0	2	6
	Free amino acids (mg/g dry tissue)		
Taurine	2.25	3.28	2.53
Aspartic acid	0.28	N/A	0.20
Threonine	0.96	2.36	2.37
Serine	6.94	9.87	10.47
Glutamic	0.78	1.26	1.40
Proline	1.69	5.26	4.17
Glycine	5.04	8.86	6.70
Alanine	4.06	8.27	7.30
Valine	1.28	2.10	1.97
Methionine	0.42	0.95	1.03
Isoleucine	0.44	1.02	0.87
Leucine	0.83	1.64	1.37
Tyrosine	0.44	1.66	1.00
Phenylalanine	N/A	0.94	0.83
Lysine	3.05	6.10	5.07
Histidine	2.12	3.32	3.37
Arginine	35.72	33.47	34.10
Ammonia	0.30	0.80	0.67
Total	66.60	91.16	85.42
SEM	1.45	1.85	0.52

Chapter III

Time and Motion Studies on Processing Freshwater Prawns

J. L. Silva, J. O. Hearnsberger, G. R. Ammerman, and G. P. Abide

In September 1985, a preliminary time study on deheading prawns was conducted at the Food Processing Laboratories at Mississippi State University. Six experienced prawn workers were chosen for this study.

Materials and Methods

Prawn workers were chosen at random and were observed without their knowledge. The number of prawns deheaded per unit of time was tabulated. This time reflected how long it took the person to dehead the washed prawns under continuous operating conditions. In most cases, 100 prawns per person per each random time were deheaded. Motion studies were conducted for each prawn size or morphotype.

Results and Discussion

Results (Table 3.1) show that, except in the case of jumbo prawns, one person can dehead 100 prawns in 5.5-5.8 minutes. This is equivalent to approximately 1,000 prawns deheaded per hour of operation. In the case of jumbos, the long deheading time (9.0 minutes) may have been caused by the difficulty in handling larger prawns. An experienced shrimp worker can dehead 120 pounds of shrimp per hour, peel 40 pounds of shrimp per hour, and peel and devein 10.8 to 13.2 pounds per hour (26- to 40-count shrimp) (Hearnsberger, 1987).

Table 3.2 shows the approximate capacity of a commercial shrimp peeler by category (size) of prawn. The Model 35 Jonsson (Gregor Jonsson Assoc., Highland Park, IL) shrimp peeler was tested at the MSU Food Processing Laboratories during September 1986. Positive results were found with the peeler, with very little down-time and excellent flexibility, insofar as adjusting for prawn size. Down-time was mostly attributed to the inexperience of the operators and the lack of a complete tail in some of the prawns for the machine to grasp. Generally, the peeler worked at a speed beyond the capability of the operator to keep the peeler supplied.

Conclusions

The results of this study indicate that an average of four deheaders and one operator can keep one peeler working at minimum capacity, producing 80 to 1,000 pounds per hour of peeled prawns, depending on the size.

Table 3.1. Time to dehead by hand 100 prawns of different sizes (categories).

Prawn category	Avg count (prawns/lb)	Total whole wt (lb)	Deheading time (min)	Deheaded wt (lb)	Deheaded yield (%)
Jumbo	6.6	15.1	9.0	6.1	40.6
Large	8.5	11.7 (±0.8)[1]	5.6 (±2.1)	5.6 (±0.8)	48.1
Medium	17.6	5.7 (±0.7)	5.8 (±0.6)	3.0 (±0.2)	52.1
Small	45.5	2.2 (±0.3)	5.6 (±1.0)	1.2 (±0.2)	56.0
BE Female[2]	15.7	6.4 (±0.5)	5.5 (±1.3)	3.4 (±0.1)	53.1

[1] Standard deviations of 100 observations, in parenthesis.

[2] Berried or egg containing females.

Table 3.2. Approximate capacity of a Jonsson Model 35[1] shrimp peeling machine for peeling prawns of different sizes.

Prawn category	Live count range (prawns/lb)	Peeling capacity (lb/hr)	
		5,000 prawns/hr[1]	4,000 prawns/hr[1]
Jumbo	4-7	1,250-710	1,000-570
Large	9-14	620-350	800-280
Medium	15-20	330-250	270-200
Small	36-50	140-100	115-80
BE-Female[2]	15-20	330-250	270-200

[1] From Gregor Jonsson Associates, Inc. 1986. "Model 35 Jonsson Shrimp Peeling Machine for Universal Processing," Highland Park, IL.

[2] Berried or egg-containing females.

Chapter IV

Prediction of Tail and Meat Weight of Freshwater Prawns

J. L. Silva and G. R. Ammerman

Processing yields for freshwater prawns are known to be dependent on the size and sex of the animals (Smith et al., 1980). In tropical areas, freshwater prawns can be selectively harvested because they can be seeded and grown year around. However, in more temperate climates, such as Mississippi, juvenile prawns are stocked only at the beginning of the growing season in May and harvested with the onset of the cool weather in September or early October (D'Abramo et al., 1986, 1988).

This type of highly seasonal single harvest, coupled with a wide range of prawn size within the population requires grading by morphotype and size to achieve maximum marketability. Dillard et al. (1986) studied the acceptability of various sizes of freshwater prawns prepared in different forms and found that the size of prawns affected the type of cooking and the consumer acceptability.

This study provides information on prediction of tail and meat weight of freshwater prawns by size-grade category, from whole and tail weight, respectively.

Materials and Methods

Freshwater prawns harvested during September 1985, were size graded by trained personnel working under the supervision of food technologists in the MAFES Food Processing facilities. Approximately 150 pounds of harvested, chill-killed prawns were divided into five categories: small, medium, large, jumbo, and females with eggs. Whole prawns were weighed individually before and after deheading and shelling. Data are reported in terms of whole, tail, and meat (tail meat, peeled) weight in grams. All animals were manually handled and processed.

Data were analyzed using the REG procedure (SAS, 1985) at the MAFES Experimental Statistics Laboratory. For overall prediction equations, test of homogeneity of equations (Boyle, 1987) was done using analysis of covariance (Johnston, 1972).

Results and Discussion

The categories, by type, are described in terms of size, range, and count in Table 4.1. The prediction equations for tail weight (with shell) from whole prawn weight for each category were significant ($P<0.05$). The coefficient of determination (R^2) was larger than 0.80 in all cases except for the overall prediction equation ($R^2 = 0.598$) (Table 4.2). The regression coefficient (slope) decreased with increased ($P < 0.05$) prawn size, except for the females, which

Table 4.1. Categories of freshwater prawns by size type.

Category (type)	Whole mean weight (g)	Weight range (g)	Mean count (no./lb)	Count range (no./lb)
Small	9.4	5.5-14.6	48	83-31
Medium	29.8	15.0-43.2	15	30-11
Large	54.1	38.4-76.2	8	12-6
Jumbo	81.6	54.5-99.9	6	8-5
Female (w/eggs)	42.1	28.2-62.4	11	16-7

Table 4.2. Tail weight prediction of prawns from wholeweight by category.

Category	Tail weight* prediction (g)	R^2	CV
Small	$0.509X(\pm 0.012)+0.486(\pm 0.114)$	0.979	3.51
Medium	$0.505X(\pm 0.013)+0.633(\pm 0.370)$	0.979	3.70
Large	$0.406X(\pm 0.023)+4.709(\pm 1.262)$	0.882	5.04
Jumbo	$0.394X(\pm 0.030)+4.503(\pm 2.450)$	0.809	5.88
Female (w/eggs)	$0.508X(\pm 0.021)+2.314(\pm 0.891)$	0.935	4.30
Overall	$0.433X(\pm 0.006)+2.800(\pm 0.275)$	0.598	6.12

* Standard error of the estimate in parenthesis.
CV – Coefficient of Variability.
X – Whole weight in grams.

showed a slope equal to the one for the small size prawns. This decrease in slope reflects a relative decrease in tail weight with increased prawn size. This is the result of the disproportionate growth of the head as compared to the body of the prawns. As the animal grows, the head containing the claws becomes heavier resulting in a lower tail to head ratio (Smith et al., 1978). Large dominant males, called 'blue claws,' have relatively heavy claws that contribute to the lower tail (with shell) yield. The high tail yield for the females is a result of the egg mass that they carry underneath the tail. This category of prawns would have to be peeled and the eggs removed before marketing because of the appearance.

Similar results were obtained for prediction of meat weight from tails (Table 4.3). Both small and medium prawns showed similar slopes within category. The slope for females was lower ($P<0.05$) because of the egg mass lost during peeling. This egg mass can be removed manually when hand peeling, or mechanically with no additional effort. The prediction equations for meat weight (grams) from tail weight (grams) for small and medium-size prawns combined ($R^2 = 0.996$) and for females with eggs ($R^2=0.897$) are shown in Table 4.3.

Size categories of freshwater prawns. From left: jumbo (orange and blue claw), large, medium, and small. Not pictured are females with eggs.

A summary of tail (with shell) and meat (tail without shell) yields for five categories of freshwater prawns are shown in Table 4.4. It was shown that the shell accounts for less than 20% of the tail weight and that the egg mass of female prawns accounts for about half of the losses in tail meat for the female prawns. Observations obtained in 1986 (data not reported) showed that meat yield for prawns peeled by a commercial shrimp peeling machine was similar to meat yield for prawns peeled by hand.

Conclusions

Although price of shrimp and of prawns increases with size of the animal, a lower yield of "marketable" meat is obtained. Economic analysis of two production schemes (Clardy et al., 1985) showed that larger revenues per unit weight harvested were obtained with medium-size prawns than with small-size prawns. The yield of prawns is controlled strictly by size and sex, thus, marketable yield will have to be controlled at the production stage (farm) and not at the processing stage.

Table 4.3. Tail meat weight prediction from whole weight of prawns by category.

Category	Meat weight* Prediction (g)	R^2	CV
Small	$0.869X(\pm 0.022) - 0.301(\pm 0.120)$	0.974	4.18
Medium	$0.826X(\pm 0.016) - 0.159(\pm 0.263)$	0.983	2.92
Small & Medium	$0.820X(\pm 0.006) - 0.056(\pm 0.066)$	0.996	3.42
Female	$0.580X(\pm 0.030) + 1.389(\pm 0.727)$	0.897	5.14

* Standard error of the estimate in parenthesis.
CV = Coefficient of Variability.
X = Whole weight in grams.

Table 4.4. Processing yields for freshwater prawns by category.

Category	Tail yield[1] (%)	Meat yield[2] (%)	Meat from tail yield[3] (%)
Small	55.9	45.4	81.1
Medium	52.5	42.9	81.6
Large	48.6	N/A	N/A
Jumbo	44.5	N/A	N/A
Female	56.2	35.8	63.7

[1] Tail (with shell) yield $= \frac{\text{Tail wt.}}{\text{Whole wt.}} \times 100$

[2] Meat (tail without shell) yield $= \frac{\text{Meat wt.}}{\text{Whole wt.}} \times 100$

[3] Meat from tail yield $= \frac{\text{Meat wt.}}{\text{Tail wt.}} \times 100$

N/A = Data not available.

Chapter V

Preservation of Freshwater Prawns Under Refrigerated and Iced Conditions

J. L. Silva, G. R. Ammerman, V. Woodruff, and S. Bradway

Previous studies have shown that whole prawns will keep on ice for up to 10 days (Angel et al., 1981) and that the prawns in the bottom layer of the ice will become mushy more quickly (Angel et al., 1985) but will remain acceptable for up to 9 days compared to 11 days for the prawns in the upper layer.

Other studies have shown a considerable decrease in eating quality in prawns held for more than 3 days under ice-chilled conditions (Nip et al., 1985b). Passey et al. (1983) reported a shelf-life of 8-9 days on whole, chilled prawns packed in a CO_2 atmosphere and kept at 4°C.

Refrigerated Prawns

Materials and Methods

The refrigerated shelf-life of whole freshwater prawns was studied in 1985. Prawns were received at the Food Processing Laboratory at Mississippi State University, washed, and given one of the following treatments: (1) a dip in a 0.3% (w/v) sorbic acid solution at 40°F (4°C) for 20 minutes to inhibit surface microbial buildup; (2) blanching for 3 minutes in

Table 5.1. Odor and color scores[1] for freshwater prawns stored at 35°F.

Attribute and treatment	Days of storage 1	4	6	8
Odor				
Control	4.8 a[2]	4.2 b	4.2 b	3.2 c
Blanched	5.0 a	4.2 b	4.4 b	3.8 b
Sorbic Acid	5.0 a	4.2 b	4.2 b	3.2 c
Color				
Control	5.0 a	5.0 a	4.4 b	4.0 b
Blanched	5.0 a	4.8 a	4.8 a	3.8 b
Sorbic Acid	5.0 a	5.0 a	4.4 b	3.8 b

[1] Rated on a scale of 1 to 5 with 5 being "fresh" and 1 being "spoiled."

[2] Means within rows differ (P<0.05) as determined by LSD.

Table 5.2. Texture and flavor scores[1] for freshwater prawns stored at 35°F.

Attribute and treatment	Days of Storage 2	5	9
Texture			
Control	7.3 a[2]	7.8 a	5.8 b
Blanched	8.1 a	7.9 a	6.3 b
Sorbic Acid	8.3 a	7.9a	7.1 b
Flavor			
Control	8.0 a	7.7 a	7.3 b
Blanched	7.8 a	7.8 a	7.1 b
Sorbic Acid	7.9 a	7.8 a	7.8 b

[1] Rated on a 9-point hedonic scale with 9 being "like extremely" and 1 being "dislike extremely."

[2] Means within rows followed by different letter differ significantly (P<0.05) as determined by LSD.

water at 212°F (100°C); and (3) a control treatment. Three replications of each treatment combination for a total of 762 pawns were involved in this study. The prawns were cooled and packed in 2.7-mil polyethylene bags and stored at 35°F (2°C) for the length of the study.

The raw prawns were evaluated visually for color and odor at days 1, 4, 6, and 8. They were subsequently boiled for 8 minutes and the meat evaluated for texture and flavor. The evaluation of the raw prawns was performed by trained panelists using a 5-point rating scale, with 5 being "fresh" and 1 being "spoiled." Boiled prawns were evaluated by trained taste panelists on a 9-point hedonic scale, with 9 being "like extremely" and 1 being "dislike extremely."

Results and Discussion

Results for odor and color scores are shown in Table 5.1. The prawns were very acceptable for color and odor for the first 6 days of storage. By the eighth day of storage, the color and odor scores were 4 or less for all treatments. Overall, the prawns received lower odor scores than color scores. Color of the prawns was acceptable for all treatments at the end of 8 days of storage although black spots, an indication of spoilage, were noticeable, especially in the non-blanched prawns.

Table 5.2 shows texture and flavor scores for the prawns stored at 35°F (2°C). All the samples were very acceptable after 5 days storage. At the ninth day, the control and blanched samples were "soft" and "mushy" in texture and were scored lower in flavor than the sorbic acid samples. The sorbic acid treatment may have inhibited or decreased the growth of spoilage bacteria and thus prevented some of the off-flavors from spoilage bacteria. Although the prawns were, for the most part, acceptable after 8 days in refrigerated storage, the microbial count was not followed in all samples and the overall appearance was not the same as the fresh prawns. Thus, not more than 8 days are recommended for storing prawns in 2.7-mil polyethylene bags at 35°F (2°C).

Iced Prawns

Materials and Methods

The second part of this study evaluated the shelf-life of freshwater prawns stored in ice. Whole prawns were received, washed, and divided into two lots. One lot was subjected to a blanch treatment by boiling at 212°F (100°C) for 3 minutes. Both treatments were replicated three times with a total of 762 prawns used in the study.

The prawns were stored in ice chests and kept in ice as needed for the duration of the study. The prawns were evaluated for odor, texture, and flavor by trained taste panelists using a 9-point hedonic scale. Tex-

Table 5.3. Mean sensory scores[1] on whole freshwater prawns stored in ice.

Attribute and treatment	Days of storage 0	5	9	12	16
Odor					
Raw	7.9 a[2]	7.6 ab	7.6 ab	7.7 ab	6.6 b
Blanched	8.1 a	7.8 a	7.6 ab	7.6 ab	6.8 b
Texture					
Raw	7.2 a	7.4 a	6.6 b	6.8 ab	6.8 ab
Blanched	7.5 a	7.5 a	7.1 ab	6.6 b	6.6 b
Flavor					
Raw	7.9 a	7.3 b	7.2 b	7.4 ab	6.5 c
Blanched	8.1 a	7.5 b	7.7 ab	6.8 c	6.2 d

[1] On a 9-point hedonic scale with 9 being "like extremely" and 1 being "dislike extremely."

[2] Means within rows followed by different letter differ significantly (P<0.05) as determined by the LSD.

ture was also evaluated by a shear press (FTC, Rockville, MD) using the peak of the shear force curve per 40 grams of sample as an indication of prawn meat firmness.

Results and Discussion

Table 5.3 shows taste panel scores on the whole iced prawns for the 16 days storage. Both treatments yielded prawns that were highly acceptable after 12 days storage in ice as indicated by the odor scores. The prawns developed a "strong" off-odor by the 16th day of storage. Texture scores fluctuated for both treatments. The blanched prawns were highly acceptable in firmness after 9 days of storage but the scores declined thereafter, although they were still acceptable. Flavor of the raw prawns was acceptable after 12 days of storage. By the 16th day of storage, the prawns had scored less acceptable on flavor.

The shear press values for the prawns increased ($P<0.05$) with time of storage as shown in Table 5.4. This indicates increased toughness of the prawns with storage time, probably because they lost moisture. This was confirmed by the taste panelists, who indicated that the prawns were "brittle" and "dry" at the 14th day of storage. The blanched prawns had higher ($P<0.05$) shear press values because moisture was lost during blanching, resulting in shrinkage of the meat and some protein coagulation, forming a stronger muscle bond. This data showed that whole freshwater prawns stored in ice remained acceptable to the consumer for a minimum of 12 days.

Table 5.4. Shear press values[1] for whole freshwater prawns stored in ice.

	Storage Time (days)		
Treatment	**0**	**7**	**14**
	Shear force (lb/40g)		
Raw	232 aA[2,3]	228 aA	253 bA
Blanched	292 abB	278 aB	331 bB

[1] Peak values of shear force curves standardized to 40 grams of sample.

[2] Means within rows followed by different lower case letter (ab) differ significantly ($P<0.05$) as determined by LSD.

[3] Means within columns followed by different capital letter (AB) differ significantly ($P<0.05$) as determined by LSD.

NOT
BLANCH
3

Whole freshwater prawns were held in ice chests to simulate ice-holding and storing in the market.

Chapter VI

The Effect of Precooking, Packaging, and Storage Temperature on Shelf-Life of Deheaded Freshwater Prawns

J. L. Silva and G. R. Ammerman

The objectives of this study were to determine the organoleptical acceptability; to determine the development of oxidative rancidity and the liberation of free fatty acids as related to precooking, packaging, and storage temperature; and to determine the shelf-life of deheaded freshwater prawns.

Materials and Methods

Materials

Chill-killed freshwater prawns were obtained from the MAFES aquaculture research facilities in 1984. The prawns were kept in ice for up to 6 housr before being packed and frozen.

Experimental design

A 2x2x2x7 factorial design with a single replication was used and the mean squares of high order interactions were used to estimate the residual error (Cochran and Cox, 1957). A total of 1,680 prawns were analyzed. The treatments were: (1) precooking for 3 minutes in boiling water vs. raw or uncooked; (2) storage of glazed prawns in waxed cartons vs. storage in polymylar pouches with vacuum imposed; (3) storage of prawns at –19°C vs. storage at –23°C; and (4) different frozen storage times (0, 2, 4, 6 , 8, 10, 12 months). All the results were analyzed statistically by analysis of variance. The means were separated by Least Significant Differences (LSD) (Steel and Torrie, 1980).

Precooking and control

Whole prawns were washed and divided into two lots. One lot was subjected to a boiling water treatment for 3 minutes and cooled in iced water. The other lot served as an untreated control. Both lots were subsequently deheaded and rewashed.

Packaging

The two lots were each divided into two sub-lots. The packaging treatments consisted of wax-coated, 5-pound shrimp boxes and 1.5-mil polymylar bags under vacuum. Fourteen prawns were placed in each box, a layer of water added, then frozen in a blast freezer to –18°C and top-glazed by spraying chilled water over them.

Another treatment consisted of packaging 14 headless prawns in 1.5-mil polymylar pouches and subjecting them to 700 mm Hg vacuum and sealing by using a Kenfield Vacuum Sealer, Model C14-E (Kenfield Corp., Skokie, IL).

Storage

Half of the sub-lots from each packaging experimental factor were stored at –18°C. The other half were stored at –23°C. The prawns were evaluated every 2 months for one year, with the day after the prawns were frozen considered to be zero time.

Deheaded prawns after being water blanched in a steam-jacketed kettle.

Chemical Analysis

TBA value, free fatty acids and fatty acids profiles were measured. The sampling and analytical procedures were the same as those described in Chapter 2.

Sensory evaluation

Sensory evaluation of the headless prawns was conducted by thawing the prawns overnight at 2°C, cooking them in boiling water for 8 minutes, and cooling to room temperature. Six trained panelists evaluated each sample for odor, appearance, texture, and flavor. A 9-point hedonic scale was used to rank the samples, with 9 being "like extremely" and 1 being "dislike extremely." The overall acceptability was obtained by averaging the four sensory factors from each panelist.

Results and Discussion

Fatty acid profile

There appeared to be no effect on the fatty acid composition of headless frozen prawns due to blanching, packaging or frozen storage temperature (data not shown).

TBA values

Table 6.1 shows the TBA values for headless, frozen prawns stored from 0 to 12 months under various conditions of blanching, packaging, and storage temperatures. The TBA values did not change for the first 10 months of frozen storage but increased significantly after 12 months. This agrees with previous studies (Reddy et al., 1981; Nakayama and Yamamoto, 1977) with frozen prawns and frozen minced fish flesh.

Table 6.1. Effect of storage time, blanching, packaging and storage temperature on TBA values of headless, frozen prawns.

Treatment	TBA value[1]
Storage time (months)	
0	0.42 a[2]
2	0.41 a
4	0.47 a
6	0.43 a
8	0.47 a
10	0.42 a
12	0.53 b
Blanching	
Blanched	0.45 a
Not blanched	0.45 a
Packaging	
Vacuum	0.45 a
Atmospheric	0.45 a
Storage temperature (°C)	
-23°	0.44 a
-18°	0.46 b

[1] mg of malonaldehyde per kg of prawn meat.

[2] Means not followed by same letter differ significantly ($P<0.05$) as determined by LSD.

Table 6.2. Effect of length of storage and temperature of storage on the free fatty acids of headless,frozen prawns.

Treatment	Free Fatty Acids[1]
Storage time (months)	
2	0.10 a[2]
4	0.13 b
8	0.13 b
10	0.14 b
Storage temperature (°C)	
-23°	0.11 a
-18°	0.14 b

[1] Percent oleic acid on a whole sample basis.

[2] Means within treatment not followed by the same letter differ significantly ($P<0.05$) as determined by LSD.

Neither blanching nor packaging under vacuum had any effect on TBA values. The TBA values for headless prawns stored at -23°C were significantly lower than the TBA values for prawns stored at -18°C. However, none of the individual TBA values for frozen prawns analyzed exceeded 0.62.

Sinnhuber and Yu (1958) reported that a TBA value of 3 represented a highly acceptable product for frozen seafoods. Fisher and Ammerman (1983) reported that frozen channel catfish with TBA values as high as 0.79 were very acceptable by taste panelists. Silva and Ammerman (1984) showed that a TBA value of 2 represents a highly acceptable frozen channel catfish.

The range of TBA values in this study agrees well with that reported by Angel et al. (1981). Prawns appear to be stable to oxidative rancidity during frozen storage regardless of blanching, packaging, or frozen storage temperature.

Free fatty acids

The effect of length of storage and temperature at which prawns were stored on the free fatty acid content of headless, frozen prawns is reported in Table 6.2. There were no significant interactions. The free fatty acids increased significantly after 4 months of frozen storage then remained constant through the tenth month. Headless, frozen prawns stored at -23°C for 10 months had a lower free fatty acid content than those stored at -18°C for 10 months. The content of free fatty acids (FFA) after 10 months of frozen storage for headless, frozen prawns was 0.14%. This value is well below the 3.35% FFA reported by Yang and Ammerman (1983) for completely acceptable frozen channel catfish after 12 months of frozen storage. Sanneh and Ammerman (1984) reported that catfish with values of 7.13% FFA stored at –18°C after 196 days was acceptable to taste panelists.

Neither blanching nor packaging had any effect on the free fatty acids content of headless, frozen prawns after 10 months of storage.

Sensory evaluation

Figure 6.1 shows the taste panel evaluation for flavor of headless, frozen prawns during 12 months of storage. There was a significant decrease in the flavor score after 8 months of storage, but the prawns were still acceptable. The flavor scores increased after 10 months of frozen storage and then decreased to a score not different from the score of the fresh samples (month 0). This agrees well with Hale and Waters (1981) who showed no significant differences in flavor scores of frozen prawn tails, but only after 9 months storage at –20°C. Texture scores for headless, frozen prawns during 12 months of frozen storage are shown in Figure 6.2. The panelists did not find any differences in the overall texture of prawns after 12 months of frozen storage. An overall mean score of 7.0 on a 9-point hedonic scale indicated a very acceptable product throughout the study. There seemed to be no effect on the texture of the prawns due to blanching, packaging, or frozen storage temperature.

Overall taste panel scores for headless, frozen prawns are shown in Figure 6.3. The overall score remained constant for up to 6 months of frozen storage and then decreased to 6.7 at the eighth month. After 12 months of frozen storage, the overall acceptability score of frozen prawns did not differ from that of fresh prawns.

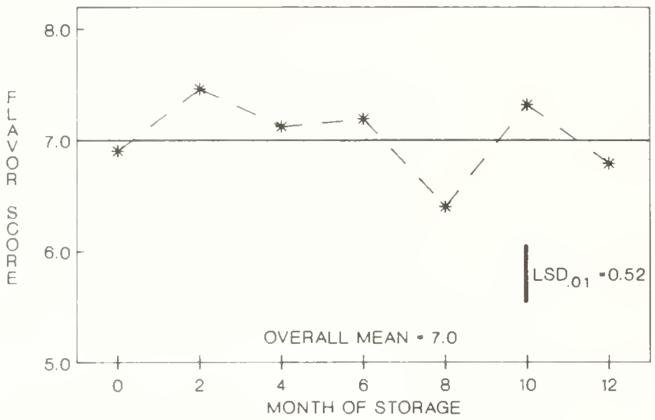

Figure 6.1. Flavor scores for headless, frozen prawns as judged by a taste panel using a 9-point hedonic

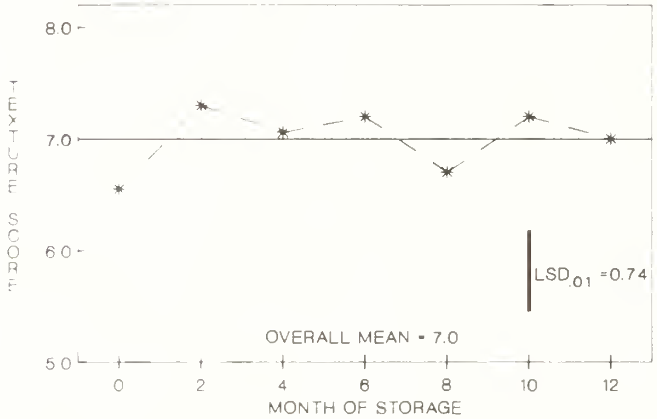

Figure 6.2. Texture scores for headless, frozen prawns as judged by a taste panel using a 9-point hedonic scale.

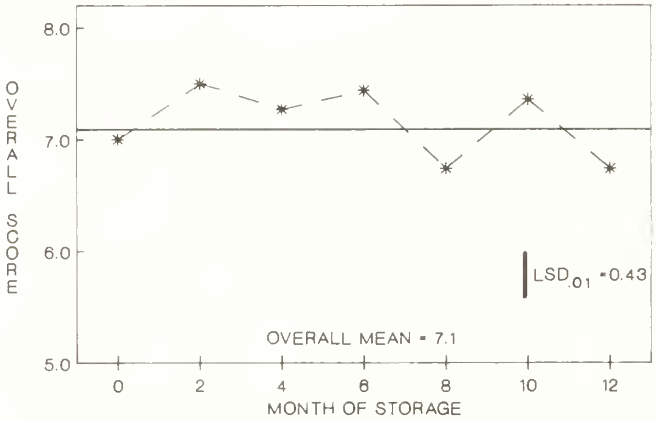

Figure 6.3. Overall acceptability of frozen, headless prawns as judged by a taste panel using a 9-point hedonic scale.

Conclusions

Headless, prawns, stored between –18 and –23°C remained highly acceptable after 12 months of storage. Although the TBA values and FFA values increased significantly after 12 months of storage, they did not reach a level associated with poor quality.

Precooking for 3 minutes in boiling water as compared to raw prawns did not have any effect in the shelf-life of the headless frozen prawns. Packaging in vacuum bags or glazing in cardboard boxes had no effect on the shelf-life of the prawns.

Chapter VII

Effect of Form of Prawn and Precooking on the Shelf-Life of Freshwater Prawns

J. L. Silva and G. R. Ammerman

Softening of the meat in freshwater prawns is attributed to a proteolytic enzyme system found in the hepatopancreas (Baranowski et al., 1984; Nip et al., 1985a). Nip et al. (1985b) reported the development of mushiness in prawn tail meat upon cooking, especially at the anterior end. The mushiness was the result of the gradual disintegration of the perimysium and endomysium, leading to the separation of the muscle fibers (Nip and Moy, 1988).

There have been contradicting reports on textural changes of whole freshwater prawns, some of which have shown significant changes in texture of prawns after as little as 1 month of frozen storage (Nip and Moy, 1979) and as long as 6 months (Miyazima and Cobb, 1977). Hale and waters (1981) reported early deterioration in texture of whole prawns compared to headless prawns (tails), stored frozen.

This research was to study the changes in frozen stored freshwater prawns as affected by form (whole vs. deheaded) and by precooking (raw vs. precooked).

Materials and Methods

Freshwater prawns raised at the MAFES aquaculture facility were chill-killed (placed in ice water for 10 minutes) and transported in ice to the Food Processing Laboratory. Half of the prawns were deheaded and washed while the other half were washed and kept whole. Half of each one of the two lots (whole and deheaded) were precooked for 3 minutes in water at 100°C (212°F). The prawns were cooled to about 20°C. Prawns from each of the four lots (replicated three times) were placed in 2.2-kg (5-lb) shrimp boxes (20 prawns per box) and frozen in a sharp freezer at –23°C. The prawns were glazed by spraying with cold water (2°C), and were stored frozen at –18°C until needed. Samples were analyzed after 0, 3, 6, 9, and 12 months of frozen storage. A total of 1,908 prawns were used in this study.

At each sampling time, prawns were analyzed for shear force and total energy necessary to shear the muscle. Five prawns were used for each measurement and the results given in units (force and energy) per gram of prawn. The procedure is described in Chapter 8. Moisture, fat, free fatty acids (FFA), and the 2-thiobarbituric acid values (TBA) were measured in duplicate samples and the values averaged. Procedures were the same as described in Chapter 2.

Sensory evaluation of the samples was conducted by eight experienced panelists. The average score of the eight panelists was taken for each of the attributes in each sample. The panelists rated the prawns on odor, appearance, texture, and flavor using a 9-point hedonic scale, with 9 being "like extremely" and 1 being "dislike extremely." The prawns were prepared by boiling for 8 minutes in water without prior thawing and presenting them to the panelists in the form of tails with the shell on. The prawns were served at room temperature (25°C).

Results and Discussion

There were no significant changes in appearance scores or absorbed energy in the prawns as related to form (whole vs. tail), precooking (raw vs. precooked) and frozen storage time (0, 3, 6, 9, 12 months).

Odor, flavor, and texture scores for the prawns were affected by precooking (Table 7.1). The raw stored prawns scored higher ($P < 0.05$) than the precooked stored prawns in all attributes. This might be the result of protein denaturation and tissue hardening upon cooking and freezing.

Table 7.1. Odor, flavor, and texture score means for freshwater prawns as affected by precooking.

	Sensory scores[1]		
Treatment	Odor	Flavor	Texture
Raw	7.3 a	7.0 a	6.8 a
Precooked	7.1 b	6.1 b	6.1 b
LSD (0.05)	0.2	0.4	0.5
CV (%)	5.8	11.1	12.0

[1] Scores are based on a 9-point hedonic scale with 9 being "like extremely" and 5 being "neither like nor dislike."

CV = Coefficient of Variability.

Table 7.3. Effect of form of prawn and time in frozen storage on mean moisture content[1] of freshwater prawns.

Form of prawn	Storage time (months)				
	0	3	6	9	12
	(%)				
Whole	77.2a[2]	76.1a	77.1a	76.0a	76.1a
Tail	77.9a	76.1a	76.4a	75.4b	71.3c
LSD (0.05)		1.8			
CV (%)		1.9			

[1] As percent moisture on a wet basis.

[2] Means within row not followed by the same letter differ significantly ($P<0.05$) as determined by LSD.

Free fatty acids (FFA) and 2-thiobarbituric acid (TBA) values varied with storage (Table 7.2). The FFA values increased and TBA values decreased. However, by the ninth month, the values for FFA decreased but increased for TBA. These values were too small to be considered important as far as fat oxidation is concerned. Odor scores fluctuated with storage time, with the lowest score of 6.8 was considered moderately acceptable on the 9-point hedonic scale.

The moisture content of the headless prawns decreased ($P<0.05$) after 12 months of frozen storage, whereas the moisture of the prawns stored whole did not decrease significantly (Table 7.3). The moisture loss in the tails is attributed to the larger surface area of tissue exposed to the air while in storage. Breakage of the ice layer (glaze) and subsequent dehydration of the tissue also caused moisture loss.

The force necessary to shear and break the prawns as affected by form, precooking, and storage time is shown in Table 7.4. The force required to shear the meat from tails was higher ($P<0.05$) than for meat from whole prawns stored for 6 months or longer. This might have been the result of dehydration and of protein denaturation during freezing since the tails have a muscle area exposed as compared to the whole prawns, which are entirely covered by their shell.

Conclusions

Freshwater prawns stored for up to 12 months at −18°C were highly acceptable to taste panelists, especially if they were not precooked. There was no significant evidence of fat oxidation, but there was some moisture loss from the tails after 12 months of frozen storage. The precooked tails appeared to get tougher after 6 months of frozen storage, possibly due to dehydration.

The data showed that prawns which are handled and frozen properly then stored raw at −18°C may be acceptable for at least one year.

Table 7.2. Mean FFA, TBA values, and odor scores of freshwater prawns during frozen storage.

Storage time (months)	FFA[1]	TBA[2]	Odor scores[3]
0	0.15 a	0.54 a	7.6 a
3	0.09 a	0.41 b	7.2 b
6	0.58 a	0.05 c	6.9 bc
9	0.09 a	0.26 c	7.4 ab
12	0.09 a	0.13 d	6.8 c
LSD (0.05)	0.16	0.05	0.31
CV (%)	96.0	22.9	5.8

[1] As percent oleic acid on a wet sample basis.

[2] As mg malonaldehyde per kg of sample.

[3] Scores are based on a 9-point hedonic scale with 9 being "like extremely" and 1 being "dislike extremely."

CV = Coefficient of Variability.

Table 7.4. Mean shear force values[1] of freshwater prawns as affected by form of prawn, precooking, and frozen storage time.

Storage time (months)	Raw		Precooked	
	Whole	Tail	Whole	Tail
	lb/g			
0	1.66 a	1.84 a	1.50 a	1.97 a
3	1.60 a	1.73 a	1.12 b	1.84 a
6	1.54 c	2.44 b	1.36 c	3.82 a
9	1.82 b	2.00 a	1.42 b	2.27 a
12	1.75 b	1.91 a	1.69 b	2.30 a
LSD (0.05)		0.42		
CV (%)		11.0		

[1] In pounds of force per gram of flesh sample.

[2] Means within storage time not followed by the same letter differ significantly ($P<0.05$) as determined by LSD.

Chapter VIII

Effect of Form, Ice-Holding and Thawing Times on the Texture and Shelf-Life of Freshwater Prawns

J. O. Hearnsberger, P. L. Silva, and J. L. Silva

The texture (softness) of freshwater prawns is the most important quality or acceptability attribute (Angel et al., 1981). Softening is brought about by collagenolytic enzymes found in the hepatopancreas of the animal (Baranowski et al., 1984). Tissue softening is attributed to the action of these enzymes on collagen in the tissue (Nip et al., 1985b).

The objectives of this study were to determine whether the softening of the prawns was caused by the prawn form, by holding prawns in ice prior to freezing, or by thawing time after freezing. Shelf-life and organoleptic acceptability of the prawns were also studied.

Materials and Methods

Chill-killed freshwater prawns from the MAFES aquaculture facilities, ranging from 30 grams to 50 grams in size, were transported in ice to the MSU Food Processing Laboratory. The prawns were held in ice for 0, 24, and 48 hours prior to processing. Half of the prawns from each ice-holding time were deheaded. The prawns were then rewashed, frozen in a sharp freezer at –23°C, packaged in 7-kg boxes lined with 1.5-mil polyethylene bags, and stored at –18°C. Samples were analyzed at 0, 6, and 12 months of frozen storage. Frozen prawns were thawed at 2°C for 0, 24, and 48 hours prior to cooking in boiling water for 8 minutes. The cooked samples were cooled in tap water and analyzed. A total of 2,430 prawns were analyzed.

The cooked samples were analyzed for shear force and total energy using an FTC Texture Test System (Food Technology Corp., Rockville, MD) with a 10-blade CS-2 standard cell (FTC) at a ram speed of 30 seconds in compression and a total pressure of 2,000 psi. The force to shear the prawns was recorded as the height of the peak on the texturegram and energy as the integral area of the texturegram as (force x distance traveled) read in the Texture Integrator. Force and energy were recorded as units per gram of sample in the cell. Tissue from three prawns (100 g) was used for each measurement.

Color values were recorded using a Hunter Color/Color Difference Meter (Hunter Associates Laboratory, Reston, VA) standardized by use of a white cell with: $L = 92.70$ (brightness); $a = -0.60$ (redness); and $b = -0.20$ (yellowness). Color was measured on three prawns from each sample placed so that they would have a continuous flat surface exposed to the color sensor. Organoleptic scores on color, firmness, chewiness, flavor and overall acceptability were conducted by a semi-trained panel using a 5-point rating scale with 5 being "excellent" and 1 being "unacceptable" (Larmond, 1977).

This study was split-plot in a completely randomized design with storage times as the whole plot treatment, and with ice holding and thawing times as the subplot treatments. The whole plot treatments were replicated three times. Data were analyzed using the analysis of variance and means were separated using Fisher's protected LSD (Steel and Torrie, 1980).

Results and Discussion

Results shown in Table 8.1 indicate that taste panelists could not detect any differences in color, flavor, and overall acceptability of the boiled freshwater prawns at zero time (fresh) or after 6 months of frozen storage. Taste panel scores indicate that deheaded prawns were firmer than whole prawns when fresh but no differences in firmness were found after 6 or 12 months of frozen storage. However, the taste panelists did find the whole prawns to be brittle as shown by the lower chewiness score after 6 and 12 months of frozen storage.

The force necessary to shear the prawns decreased after 24 hours of holding in ice and remained the same after 48 hours of ice holding for prawns stored for up to 6 months (Table 8.2). This suggests that any enzymatic action on the prawns occurs within the first 24 hours of holding and that thawing time and prawn type have little effect on texture of prawns if they are held less than 6 months in frozen storage.

Table 8.1 Mean organoleptic scores[1] for freshwater prawns as affected by storage time and type of prawn.

Storage time (months)	Type of prawns	Organoleptic scores				
		Color	Firmness	Chewiness	Flavor[NS]	Overall[NS]
0	Whole	4.0 a[2]	3.2 a	4.6 a	4.1	4.1
	Deheaded	4.1 a	4.3 b	4.3 a	4.6	4.2
6	Whole	4.0 a	3.7 a	3.7 a	4.5	3.7
	Deheaded	4.1 a	4.1 a	4.4 b	4.6	4.1
12	Whole	3.6 a	3.3 a	3.4 a	4.5	3.4
	Deheaded	4.3 b	3.9 a	4.3 b	4.3	4.0

[1] Scores were based on a 5-point rating scale with 5 being "excellent" and 1 being "unacceptable."

NS No significant differences.

[2] Means within column, within times differ significantly (P < 0.05) as determined by LSD.

Table 8.2. Mean shear force (peak height) for freshwater prawns as affected by frozen storage time and ice-holding time.

Storage time (months)	Ice time (hours)	Shear force (N/g)
0	0	57 a*
	24	46 b
	48	44 b
6	0	43 a
	24	32 b
	48	35 b

* Means within storage time not followed by the same letter differ significantly (P<0.05) as determined by LSD.

Table 8.3. Mean shear force (peak height) for freshwater prawns as affected by frozen storage time and thawing time.

Storage time (months)	Thawing time (hours)	Shear force (N/g)
0	0	50 a*
	24	49 a
	48	49 a
6	0	42 a
	24	36 b
	48	31 c

* Means within each storage time not followed by the same letter differ significantly (P<0.05) as determined by LSD.

Results on shear force values for prawns stored frozen for 6 months as affected by thawing time are shown in Table 8.3. Shear Force required to break prawn meat remained constant with no storage. However, the force necessary to shear the prawn meat decreased after 24 hours of thawing and again after 48 hours of thawing time after 6 months of frozen storage. This may be the result of higher enzyme activity due to tissue disruption in freezing of the prawns which will cause more breakdown of the collagen or prawn tissue.

Table 8.4. Mean shear force on freshwater prawns stored at –18°C for 12 months as affected by type of prawn for different ice-holding times.

Prawn type	Ice-holding time		
	0 hr	24 hr	48 hr
	----Shear force (N/g)----		
Whole	39 a*	26 a	36 a
Deheaded	41 b	54 b	33 a

* Means within row not followed by the same letter differ significantly (P<0.05) as determined by LSD.

After 12 months of frozen storage, the shear force values for tissue from stored whole prawns was less than the force from prawn tails, if kept in ice for 24 hours or less (Table 8.4). Holding in ice for 48 hours did not affect the shear force of the whole prawns but lowered the shear force of the tails.

Conclusions

The texture measurements showed no difference in shear between whole and deheaded prawns stored frozen for up to 6 months. Texture of the prawns deteriorated within the first 24 hours of ice holding and was influenced by thawing time when the prawns were stored for 6 months. After 12 months of frozen storage, whole prawns appeared to be softer than deheaded (tail) prawns regardless of thawing time and for any prawn held in ice for 24 hours or less.

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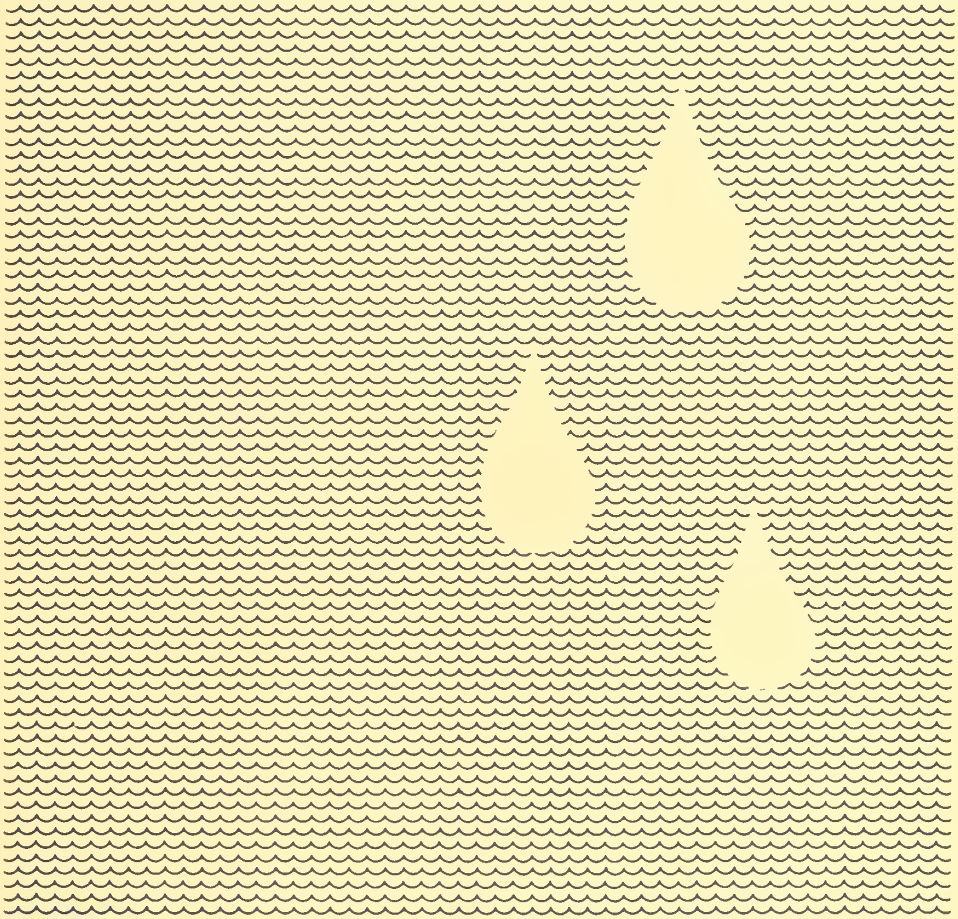
Potential for Use of Rainfall During Permanent Flood Of Rice in Mississippi



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Potential for Use of Rainfall During Permanent Flood of Rice in Mississippi

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Abstract

Rice production in the Delta of Mississippi requires large amounts of irrigation water. Most of the water is applied during a permanent flood that typically starts about June 1 and lasts through August 31. During this time, irrigation water is added to make up for water lost from the field by evapotranspiration (ET), by percolation through the soil, and by runoff from the low end of the field. Estimates of the amount of water used during this period range from 2 to 4 feet. If rainfall during this time could be held in the field, the amount of irrigation water needed could be reduced. In this study, a computer model is applied to 23 years of rainfall and weather data from Stoneville, Mississippi to estimate the long-term average potential for rainfall capture with different rice water management scenarios. The model assumes that ET is the only loss of water from the field. Loss of water through the soil was assumed to be smaller than the error associated with the ET model and was therefore assumed to be zero. The model also assumed no runoff of irrigation water.

The average rainfall for the 23-year period evaluated was only 9.5 inches during June, July, and August. This amount represents the upper limit for average rainfall capture. The simulation results indicate that with management limitations imposed by most commonly used field irrigation systems (one inlet point for the entire field), an average of about 5 inches of rainfall could be captured each season. With multiple inlets (an inlet from the water source for each levee) the average rainfall capture was about 7 inches per season.

Sensitivity analysis of the model indicated realistically expected inaccuracies (errors in pan coefficient and not including soil infiltration as a water loss) in calculating ET did not substantially effect the simulated rainfall capture and therefore did not change the basic conclusions of the analysis.

Potential for Use of Rainfall During Permanent Flood of Rice in Mississippi

Introduction

Rice production in the Delta of Mississippi requires large amounts of irrigation water, most of which is applied during a permanent flood that typically starts about June 1 and lasts through August 31. During this time, irrigation water is added to make up for water lost from the field by evapotranspiration (ET), by percolation through the soil, and by runoff from the low end of the field. Estimates of the amount of irrigation water applied during this period range from 2 to 4 feet (Griffin et al., 1984, Parsch, 1986), but applications as high as 5 feet (McCauley, 1976) to 14 feet (Robertson, 1917) have been reported.

If rainfall that occurs during permanent flood could be held in the field, the amount of irrigation water needed could be reduced. An estimate of the possible reduction in pumped irrigation water can help quantify the savings in pumping costs a grower can expect by adjusting management to capture rainfall. Furthermore, water resource planners will be able to estimate the potential shifts in ground and surface water use with irrigation management sensitive to the potentials of rainfall capture.

Brown et al. (1978) measured rainfall captured in rice fields in Texas but did not calculate the amount of rainfall actually used to replace irrigation water in the field. Very little data on actual captured rainfall in flooded rice fields are available for the Mississippi Delta region at this time. Published data from Texas (McCauley et al., 1985) and Mississippi (Massey et al., 1987) indicate that under present water management practice in those areas, most rainfall is lost to runoff. Work by Vamadevan and Dastane (1971) and Ha-Woo Chung et al. (1986), however, has shown that rainfall can be effectively used with irrigation under monsoon conditions. Chung et al. reported that in Japan about 65 percent of rainfall could be used in the rice field. Changes in management practice may therefore allow some rainfall to be held on the fields and used to meet the water demands of the crop in Mississippi.

The major environmental variables that influence irrigation requirement of rice are ET and soil infiltration rates. During the June through August flood of rice, some water is lost as water infiltrates the soil surface and percolates below the root zone. Typical rice fields of the Delta have poor infiltration and poor internal drainage. Before water can be transpired it must first infiltrate into the soil. Therefore, only water that infiltrates the soil in excess of transpiration is lost. Brown et al. (1978) found losses of water through the soil to drop to less than 0.05 inch per day after 15 days of flood on a clay soil in Texas. Similar water budgets were calculated for catfish ponds in the Delta by Pote et al. (1988). In their work, loss of water from catfish ponds through the soil was assumed to represent a minor portion of water loss from a pond and was assumed to be zero for approximating water budget calculations.

Computer models using rainfall and other weather data can be used to provide an estimate of ET of rice. Tomar and O'Toole (1979) reviewed measured rice ET data from Southeast Asia and reviewed methods of calculating ET from pan evaporation (Ep). They found the following relationship between pan evaporation and rice ET:

$$ET = K \times Ep \qquad (1)$$

where: ET = daily rice evapotranspiration during flood;

Ep = daily evaporation from a standard class A pan;

K = empirically derived constant = 1.2.

This method has been applied to the Mississippi Delta by Pennington and Wolf (1989). Their work compared estimates of ET from various models and calculated seasonal variability of rice ET under Mississippi climate conditions. The daily calculated ET values from those models can be used as a basis for the evaluation of the potential rainfall capture in rice fields. The models presented by Pennington and Wolf are expanded in this publication by adding a component that calculated daily rainfall capture under different management scenarios.

Methods

Rainfall and pan evaporation data from Stoneville, MS, were compiled for the years 1966 through 1988. These data were used to calculate daily ET using Equation 1 and rainfall capture for the model.

A simulated field was considered to be flooded to a set depth on June 1. This depth is used as a reference point for describing the amount of water in the field, and is assigned a depth value of zero as a convenient reference point. For each day, the calculated value of ET was subtracted from the simulated water levels in the rice field. On each day without rain or irrigation, the water level dropped further below zero. Rain falling on any day can be captured and added to the depth of water in the field subject to limitations that will be described later.

Two general field configurations were modeled. Both are presently used in rice production. The first is more common in the Delta.

Field Configuration 1
Single Inlet

An example of a single inlet field configuration is given in Figures 1 and 2. All water is applied to the field at a single inlet point into the first bay at the top of the field. After the first bay fills, water runs through a gate to fill the second bay (Figure 2). This pattern of bay filling continues until sufficient water has been pumped to fill all bays. The well is then turned off. At this time, the field is filled to its zero reference depth and has no capacity to store rainfall.

Immediately after the well is turned off, infiltration and ET begin to decrease the water level in the field below the zero reference depth, and the field begins to develop an increasing capacity to store rainfall. Eventually, the water level will drop to a point where the well must be turned on to refill the field. The difference between the full, zero reference level and this low point is referred to in this paper as the allowed depletion (AD). When the AD level is reached, the field is still covered with water but an irrigation must be started to maintain the flood in the field.

Numerically, AD is the depth in inches between the water level in a filled bay (zero) and the lowest water level allowed before irrigation is initiated. AD is an evaluated variable in this model and ranged from 0.25 to 5.0 inches in 0.25-inch increments. When the field reaches its AD, it has its greatest capacity to store rainfall. When AD is increased from 0.25 to 5 inches, the maximum storage capacity of the field also increases. When an irrigation is started, the well refills each bay reducing the storage capacity until the field is again full of water and the water level is at the zero reference. Due to the nature of the water delivery system in the single inlet field, each bay must be filled to get water to the next bay. Therefore, when an irrigation is completed, each bay is completely filled and at that point the field has zero capacity to store rainfall.

Rainfall can be captured in a single inlet field on days when the water level is below full. Rainfall can be added to the depth of water in the field only up to the point when the field is full and the water level is at the zero reference depth. Any rainfall in excess of that needed to fill the field was considered to be lost as runoff.

Field Configuration 2
Multiple Inlets

An example of a multiple inlet field is given in Figures 3 and 4. Water is delivered directly to each bay from a supply ditch or pipe. Occasionally the supply ditch is a narrow levee running the length of the field and all other levees are supplied with water from this supply levee. Whatever the supply method, each levee can be filled independently of all other levees in the field.

This method has several advantages over single inlet fields. First, if only a few bays in a field need water, the entire field above those bays does not have to be filled to get water to them. Also, by adding water to each bay independently, the bays do not have to be completely filled. Because the bays do not need to be completely filled, the field can almost always have some capacity to store rainfall, even after a completed irrigation. This extra capacity to store rainwater above the highest irrigation-filled level will be referred to as a field's freeboard.

In the multiple inlet field configuration, gates are placed between adjacent bays just as in the single inlet method previously described. In the multiple inlet method, the gate crests are set above the refill irrigation levels. The height of the gate above the full irrigation level determines the fields freeboard. The gates are required only to allow excess rainfall to leave the field without damage to levees and to drain the field. In work reported in this paper, the effect of freeboard on rainfall captured was evaluated for freeboard depths ranging from 0.5 to 3.0 inches in 0.25-inch increments.

Other Model Variables

(a) Allowed depletion

The model assumes that an irrigation will be initiated when the water depth in the field approaches the minimum necessary to cover the field and maintain flooded conditions. That level is the same for all AD's. The water depth to which a field is filled by irrigation is equal to the minimum depth needed to maintain flood plus the AD. This total depth will increase as AD increases. Therefore, a field with an AD of 4 inches will have 3 inches more depth of water than a field simulated with an AD of 1 inch. The extra water required to operate a field with a large AD must be accounted for in net rainfall captured. More rainfall may be captured in a field with a large AD, but the additional water needed for the large AD will reduce the net water savings from the captured rainfall. The AD of a simulation is subtracted from the total rainfall captured to calculate net reduction in pumped water. This amount is referred to as net rainfall captured.

(b) Sensitivity to constant K

The value of 1.2 for the value of K in Equation 1 is from research conducted outside of the Mississippi Delta. The value of K for the Delta may not be 1.2. To test the effect of possible errors in the value of K on simulation results and conclu-

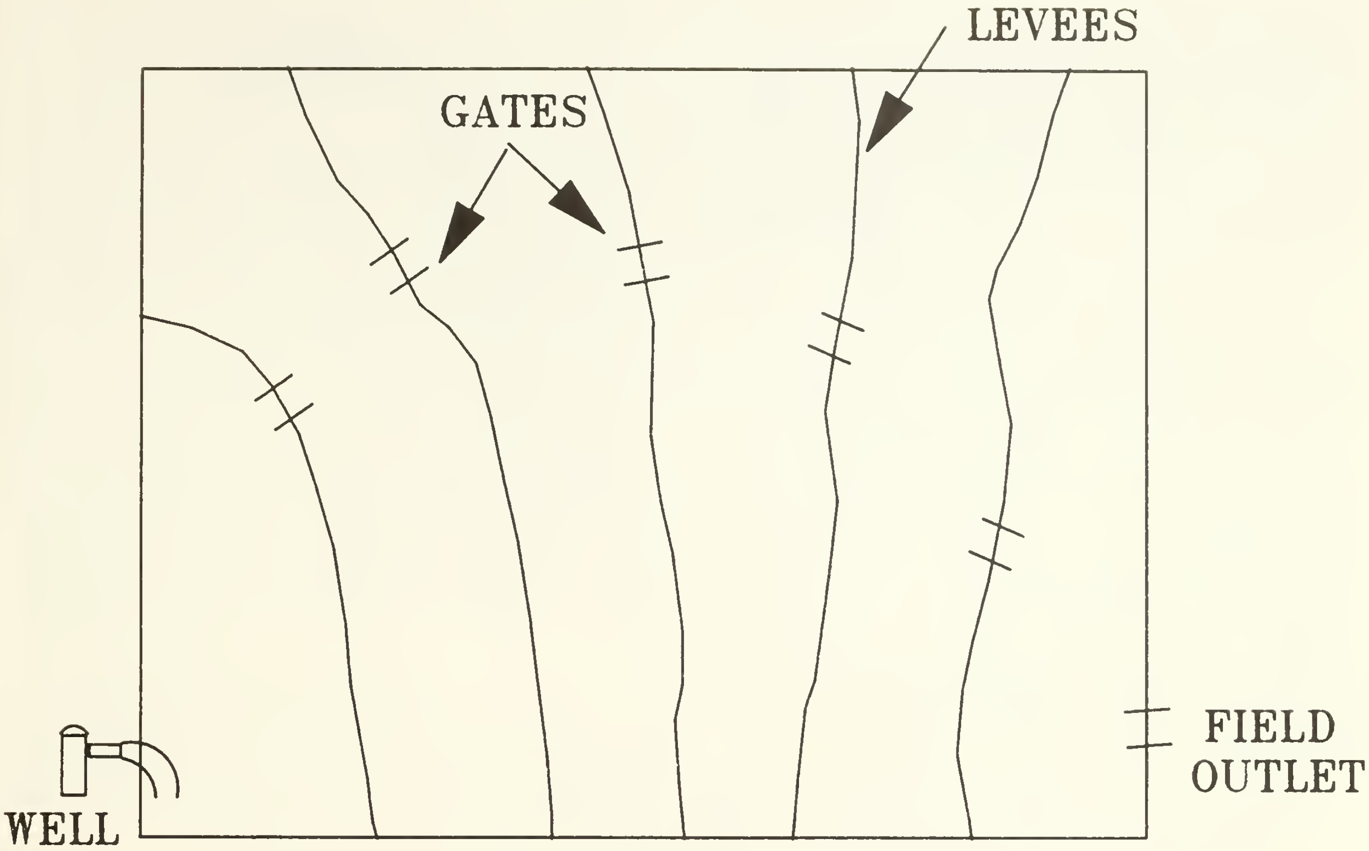
LEVEES
GATES
WELL
FIELD OUTLET

Figure 1. Single inlet field. Entire field is filled with water applied at the well. Each bay must be filled before water will flow to next bay.

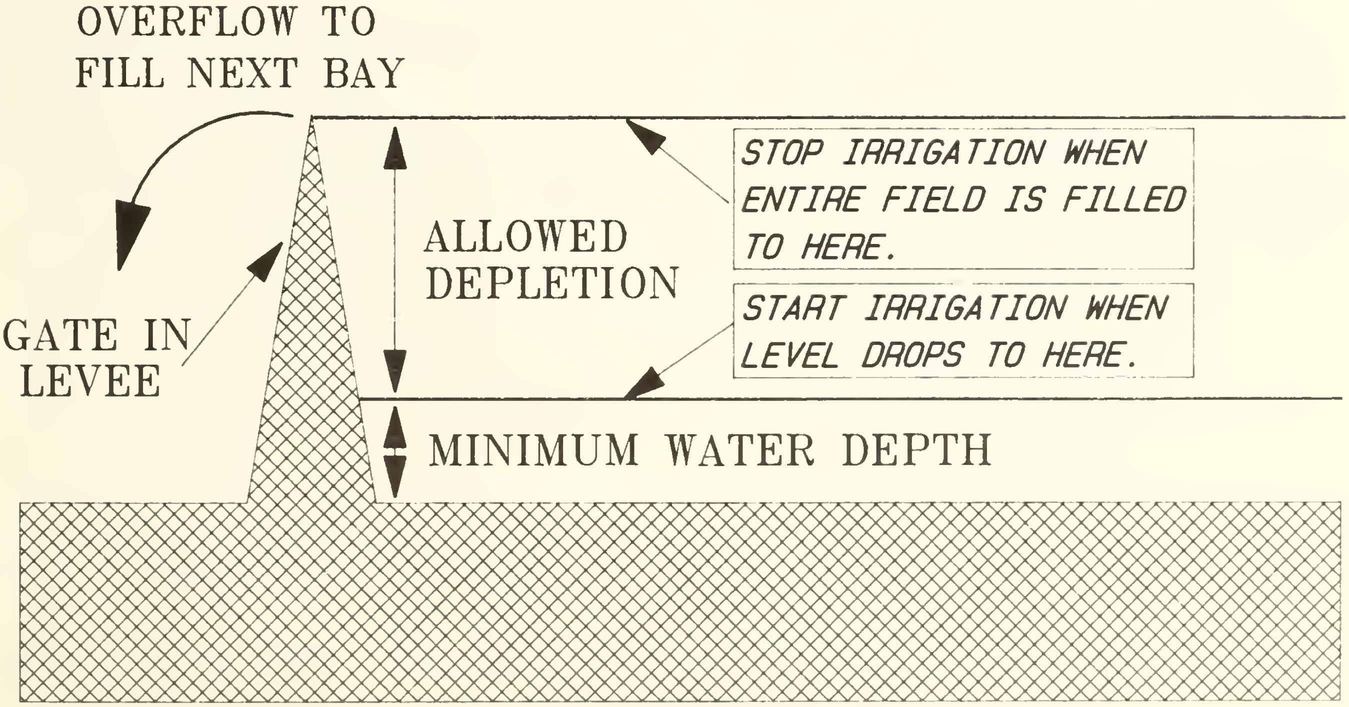
OVERFLOW TO FILL NEXT BAY
GATE IN LEVEE
ALLOWED DEPLETION
STOP IRRIGATION WHEN ENTIRE FIELD IS FILLED TO HERE.
START IRRIGATION WHEN LEVEL DROPS TO HERE.
MINIMUM WATER DEPTH

Figure 2. Cross-section of water levels and gate in levee for a field with a single field inlet.

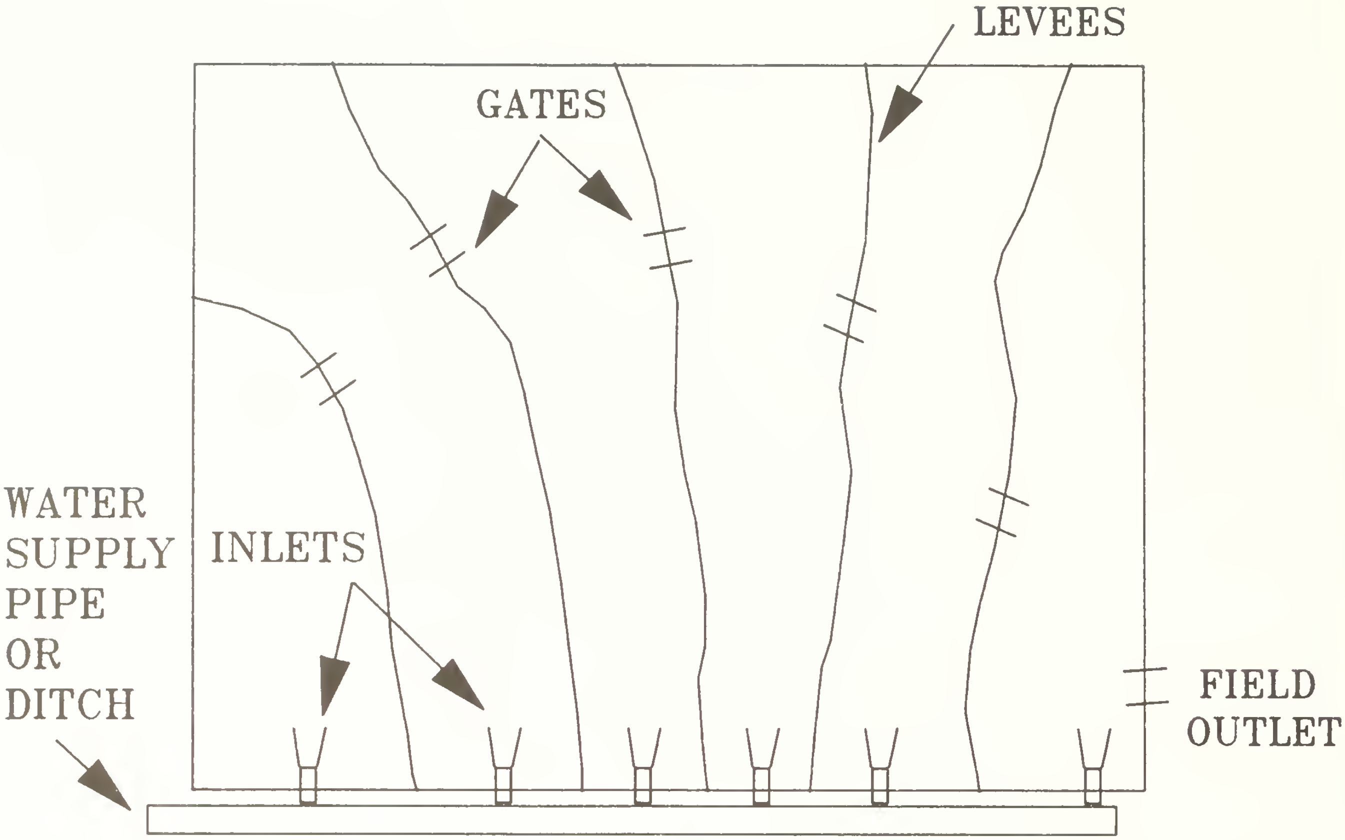
LEVEES
GATES
WATER SUPPLY PIPE OR DITCH
INLETS
FIELD OUTLET

Figure 3. Multiple inlet field. Water can be applied to each bay independent of all other bays. Gates are for rainfall runoff and draining the field.

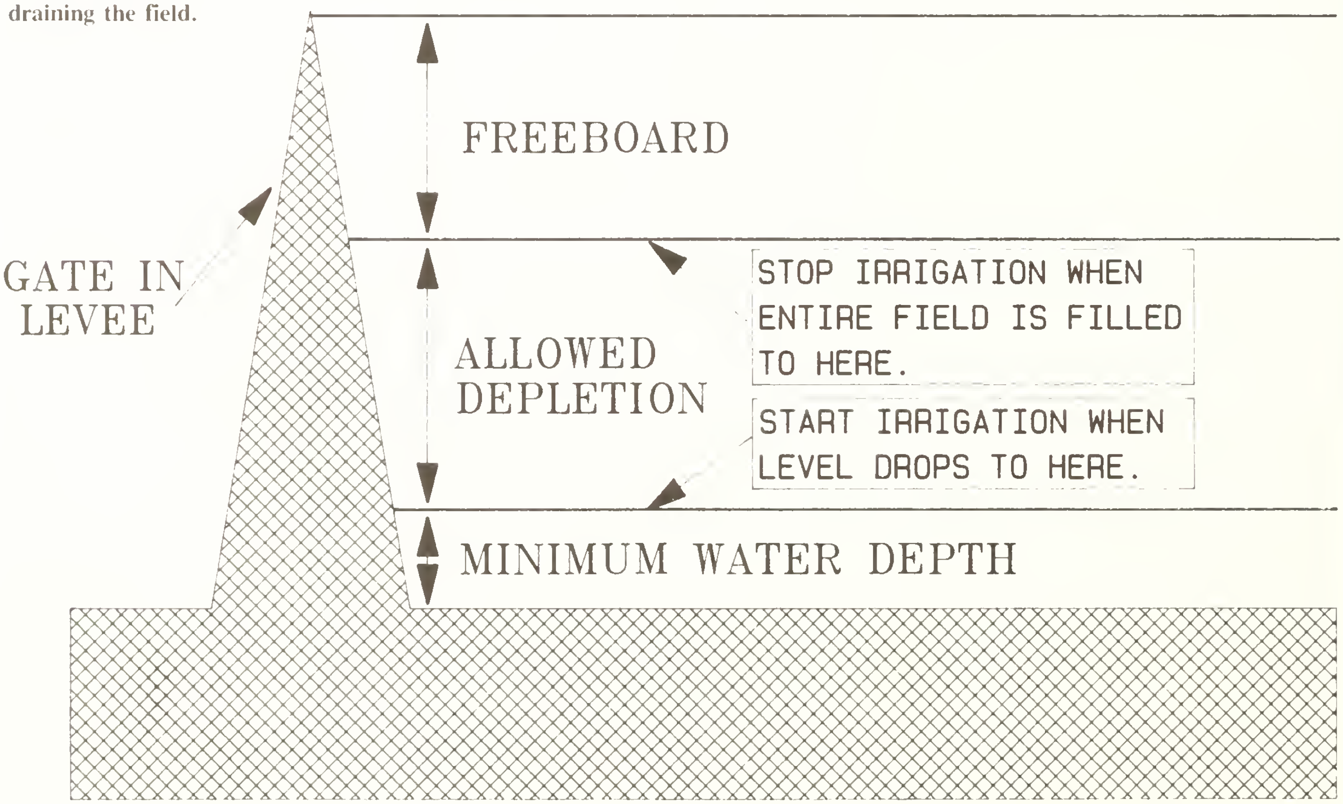
FREEBOARD
GATE IN LEVEE
ALLOWED DEPLETION
STOP IRRIGATION WHEN ENTIRE FIELD IS FILLED TO HERE.
START IRRIGATION WHEN LEVEL DROPS TO HERE.
MINIMUM WATER DEPTH

Figure 4. Cross-section of water levels and gate in levee for a field with multiple field inlets.

sions, a series of simulations were run with values of K ranging from 0.8 to 1.6.

(c) Irrigation capacity

The rate at which a rice field can be refilled by irrigation depends on both the size of the well and field. This irrigation rate can generally be described as inches of water that can be applied to the field in a single day. General irrigation guidelines suggest that a well or pump should be able to deliver at least 15 gallons of water per minute for each acre in the field. This is equivalent to about 0.8 inch per acre per day. Information on well flow rates and field sizes indicates that an irrigation rate of about 1.0 inch of water per day is commonly found in the Delta. A range of irrigation rates above and below this value is also expected. A well with an irrigation rate of 0.5 inches per day or less would need to run most of the season to stay ahead of water losses from the field. Irrigation rates from 0.5 to 2.0 inches per day were modeled to evaluate the effect of irrigation rate on potential to capture rainfall.

General model description summary

(1) The field was flooded to the required level on June 1.

(2) Daily ET was calculated from equation 1 using a specified value for K.

(3) The depth of the water in the bay was decreased by that day's ET.

(4) Rain that falls each day was added to the depth of the water in the field. Any rain in excess of the field's storage capacity was lost as runoff.

(5) Rainfall held in the field was accumulated as captured rain.

(6) When water losses from ET dropped the water level in the bay to the AD, an irrigation was initiated.

(7) Irrigation was continued until the field was refilled to the reference water level of zero. ET losses and rainfall additions were continued during irrigation.

The cycle of losses and additions continued from step 2 to 7 until the end of permanent flood on August 31.

Summary of model variables

(a) Twenty-three years of Ep and rainfall data from Stoneville, Mississippi, (1966 through 1988).

(b) AD (0 to 5 inches in 0.25-inch increments).

(c) Freeboard (0 to 3 inches in 0.5 inch increments).

(d) Coefficient K from Equation 1 (0.8 to 1.6 in 0.2 increments).

(e) Irrigation capacity (0.5, 0.75, 1.0, 1.25, 1.5, and 2.0 inches per day).

For most simulations, a K of 1.2 and an irrigation capacity of 1.0 inch per day were used.

Average rainfall captured

For each simulation, an irrigation rate and K value were specified. The model then ran all combinations of freeboard and AD on each year's weather. For a set of K, AD, freeboard, and irrigation capacity, the rainfall captured in the simulated field was calculated for each of the 23 years of weather data. The average rainfall captured over the 23-year period was recorded as the expected potential for rainfall capture for the specific set of conditions.

The model was run in a spreadsheet (Symphony) on a personal computer.

Results

Average rainfall during June, July, and August at Stoneville, Mississippi, for the period of 1966 to 1988 was 9.5 inches and ranged from 5.2 inches in 1980 to 14.1 inches in 1971. The average rainfall at Stoneville from 1960 to 1979 was reported by Hull et al. (1982) as 10.5 inches. These data indicate that about 10 inches was the long-term maximum amount of rain water that could be used in rice fields during permanent flood.

Examples of water levels during the permanent flood in a single inlet field with zero freeboard and multiple inlet field with 2 inches of freeboard are given in Figures 5 to 7. The highest rainfall year in the 23-year period evaluated was 1979 (Figure 5). At the other extreme, 1988 was a very dry year

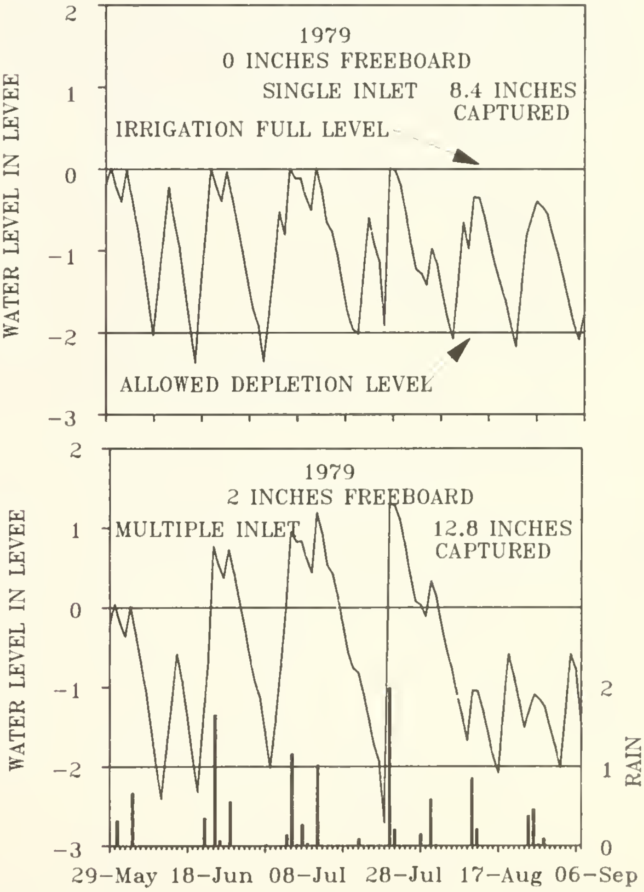

Figure 5. Simulated water levels in field for 1979 with zero and 2 inches freeboard. Zero water level is depth of water at completion of irrigation. Values above zero are rainfall captured by freeboard.

during rice permanent flood (Figure 7). Rainfall during 1987 was near the 23-year average (Figure 6). In these figures, water depth was gradually decreased by ET until the AD was reached. AD for the simulations in Figures 5 to 7 was 2 inches.

Irrigation was initiated and the field filled quickly. The primary difference between the single and multiple inlet fields was that because of freeboard, the multiple inlet field would have rainfall storage capacity even when the irrigation was completed. Because of this, multiple inlet fields consistently captured more rainfall in a season than single inlet fields. Water levels above zero represent rainfall captured due to the freeboard capacity of the multiple inlet field.

Effect of allowable depletion

Results of the 23-year average net captured rainfall for a K value of 1.2 and an irrigation capacity of 1.0 inch per day are given in Figure 8 and Table 1. In the figure, the results for a single inlet field are presented by the data at the front of the figure for zero freeboard. For the zero freeboard, single inlet field net captured rainfall increased with AD to a maximum capture of about 5 inches with an AD of 1 to 2 inches. At AD values above 2 inches, the additional water depth necessary to allow for the larger AD was usually greater than the increase in net captured rainfall. Net captured rainfall therefore decreased with AD above the 1- to 2-inch range. This result indicates that the maximum long-term savings in applied water that could be expected with rainfall capture in single inlet fields was about 5 inches.

Effect of freeboard

Increasing freeboard increased the net captured rainfall at all AD (Figures 5 through 8). The largest net captured rainfall was obtained with the smallest AD once freeboards of about 1.5 inches were reached. Very small (less than 2 inches) AD would be very difficult to manage in the field. With a typical irrigation capacity of about 1 inch per day, a manager would be required to turn wells on or off almost every day. Very frequent irrigations would increase the amount of water lost from a field due to unavoidable over irrigation and would require large amounts of management time. An AD of 2 inches would allow for more realistic management and is typical of current practices.

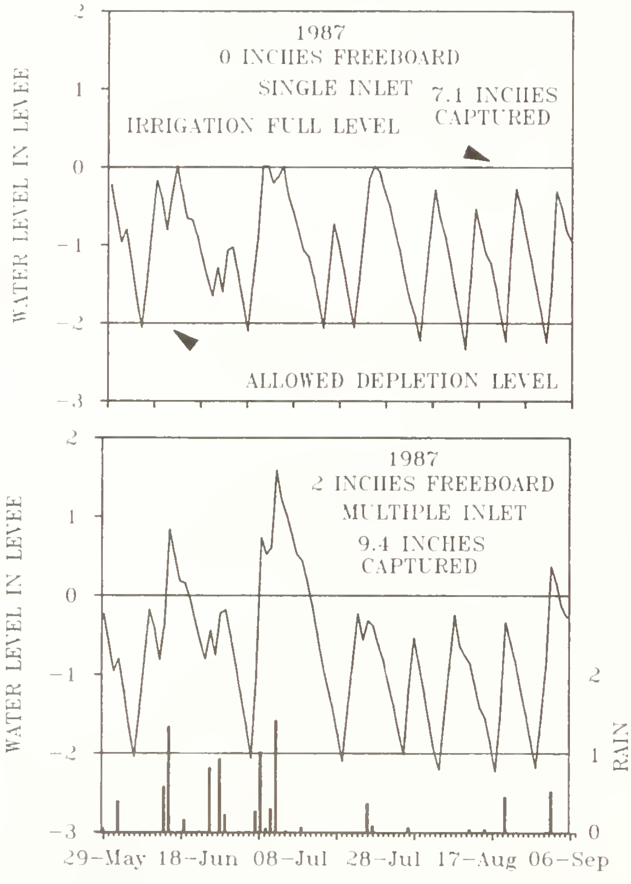

Figure 6. Simulated water levels in field for 1987 with zero and 2 inches freeboard. Zero water level is depth of water at completion of irrigation. Values above zero are rainfall captured by freeboard.

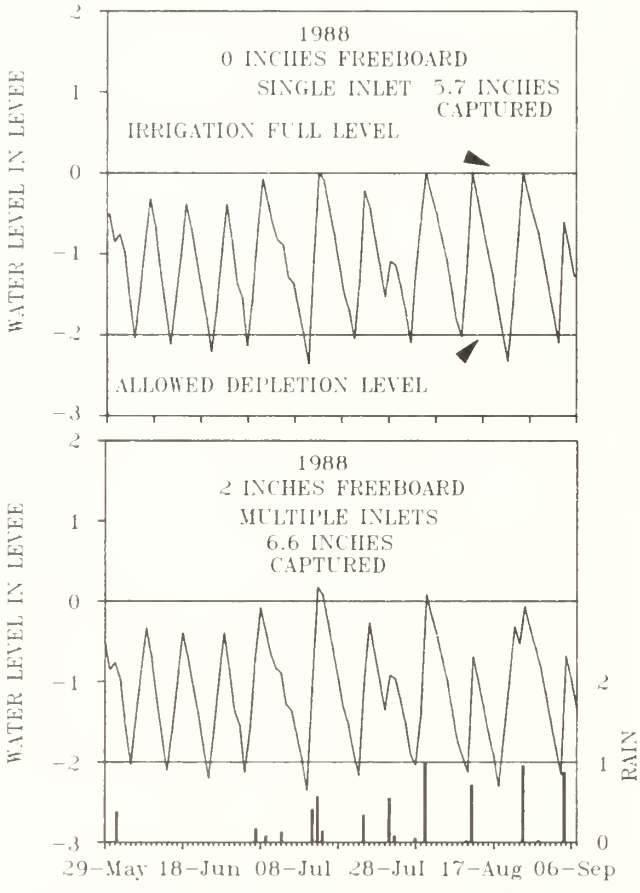

Figure 7. Simulated water levels in field for 1988 with zero and 2 inches freeboard. Zero water level is dept of water at completion of irrigation. Values above zero are rainfall captured by freeboard.

Table 1. Twenty-three-year average net captured rainfall with irrigation capacity of 1.0 inch per day and a K (from Equation 1) of 1.2. All values are in inches. Same data are presented in Figure 8.

	FREEBOARD			
ALLOWED	ZERO	1	2	3
DEPLETION	NET CAPTURED RAINFALL			
0.25	2.46	6.72	8.26	8.72
0.50	3.27	6.83	8.12	8.50
0.75	4.18	7.07	8.04	8.31
1.00	4.96	7.10	7.84	8.11
1.25	5.16	7.06	7.63	7.86
1.50	5.11	6.92	7.47	7.68
1.75	4.94	6.55	7.14	7.36
2.00	5.09	6.42	6.93	7.11
2.25	4.63	6.28	6.69	6.90
2.50	4.73	6.13	6.46	6.63
2.75	4.61	5.90	6.30	6.47
3.00	4.53	5.71	5.99	6.13
3.25	4.50	5.46	5.79	5.93
3.50	4.42	5.34	5.59	5.72
3.75	4.33	5.10	5.34	5.47
4.00	3.77	4.61	5.00	5.18
4.25	3.62	4.49	4.80	4.95
4.50	3.38	4.18	4.52	4.66
4.75	3.16	4.04	4.33	4.45
5.00	3.00	3.87	4.10	4.20

Net captured rainfall, at AD values of 2 inches or greater, is about 7 inches for all freeboards of 1 inch or more. Seven inches appears to be a realistic maximum net captured rainfall for multiple inlet fields. This is only 2 to 3 inches more water than captured in well managed single inlet fields. As the information in Figure 8 and Table 1 suggests, 1 inch of freeboard will capture about 90 percent as much rainfall as 2 inches or more of freeboard.

Sensitivity to value of constant K

Errors in major model variables may change the results of simulations and the conclusions drawn from them. One source of potential error was in the constant K from Equation 1. This value scales Ep data to approximate rice ET. The value of K used in these simulations was 1.2 and was taken from the literature (Tomar and O'Toole, 1979). Research from which this value was drawn was not conducted in the Mississippi Delta and local conditions could require a different value. The potential effect of such an error was evaluated by running simulations of the model with different values of K and comparing the results.

The concern about accuracy of K would be reduced if a relatively wide range of K values does not produce modeled results that would change the general conclusions of the work. Selected results are given in Figure 9. The data in Figure 9 show that relatively large changes in K result in minor changes of net captured rainfall. Freeboard greatly reduces the effect

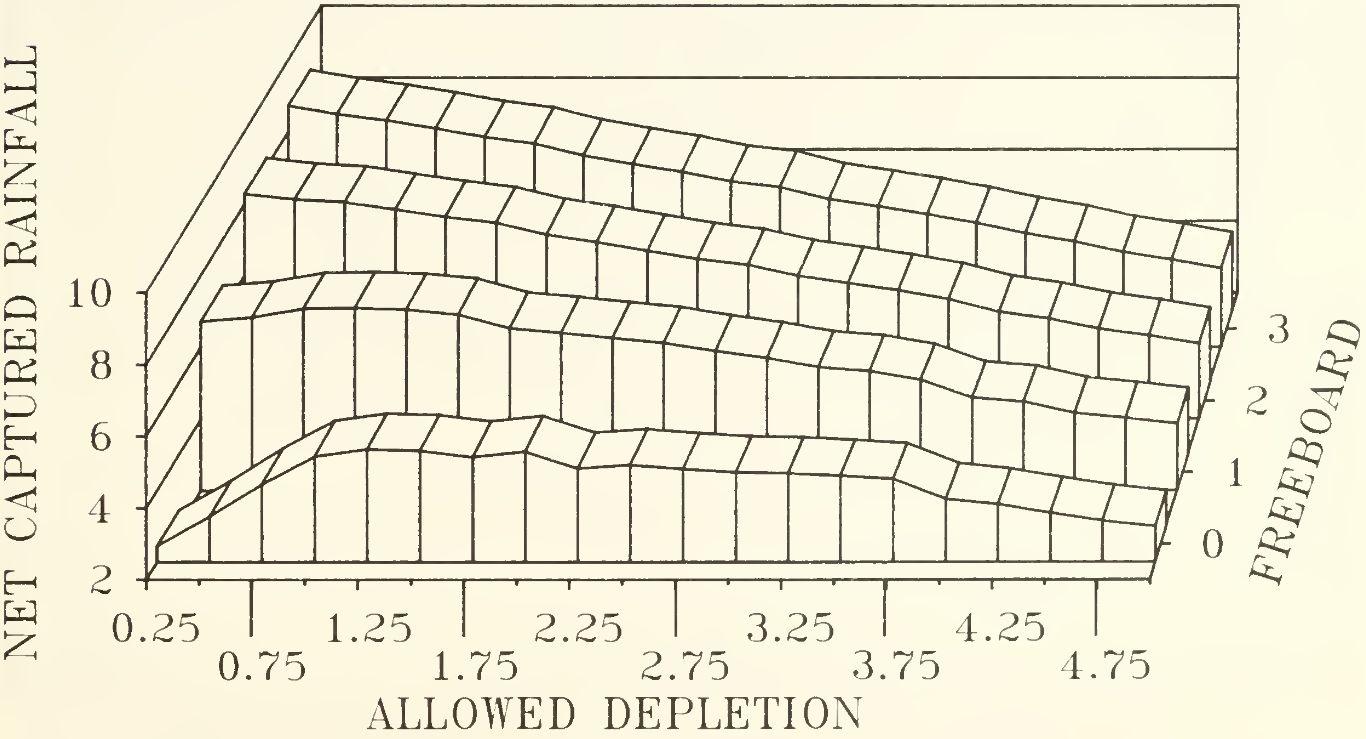

Figure 8. Twenty-three-year average net captured rainfall with irrigation capactiy of 1.0 inch per day and a K (from Equation 1) equal to 1.2. All measurements are in inches.

of K on net captured rainfall. Also, with zero freeboard, the maximum amount of net captured rainfall is very similar for all values of K, and the maximum net captured rainfall occurs at about the same range of AD for all K values. In general, inaccuracies in K will not significantly change the estimates of net captured rainfall and the conditions for maximum net captured rainfall.

The results of simulations with high values of K provide insight into the potential influence of another assumption used in the model. The model assumes that water levels in levees could be realistically modeled with ET alone assuming that soil infiltration was negligible. High levels of water loss by soil infiltration would be approximated by high values of K. Values of K greater than 1.2 mean that more water is leaving the field than expected with the selected K value of 1.2. This extra water loss could be due to more ET than expected or to a significant loss of water due to infiltration and percolation or to levee leakage.

Discussion of results of simulations with elevated K values in the previous paragraph indicated that larger values of K did not change model outcomes of net captured rainfall sufficiently to cause a change in general conclusions about he potential for rainfall capture in rice fields. This same result indicates that infiltration and percolation or levee losses of water will not change the conclusions if the water lost through the soil is significantly less than the water lost to ET.

Effect of irrigation capacity

The capacity to deliver water to a rice field influences how quickly the field can be irrigated or how fast the rice levees can be filled. Model simulations were run to determine if irrigation capacity influenced net captured rainfall. Simulations were run with irrigation capacities of 0.5 to 2.0 inches per day. Selected results are given in Figure 10. Irrigation capacity did not significantly influence net captured rainfall under any conditions used in these simulations.

Conclusions

Results of rice ET models indicated that about 5 inches of rainfall per season could be captured during permanent flood in well-managed single-inlet rice fields of the Mississip-

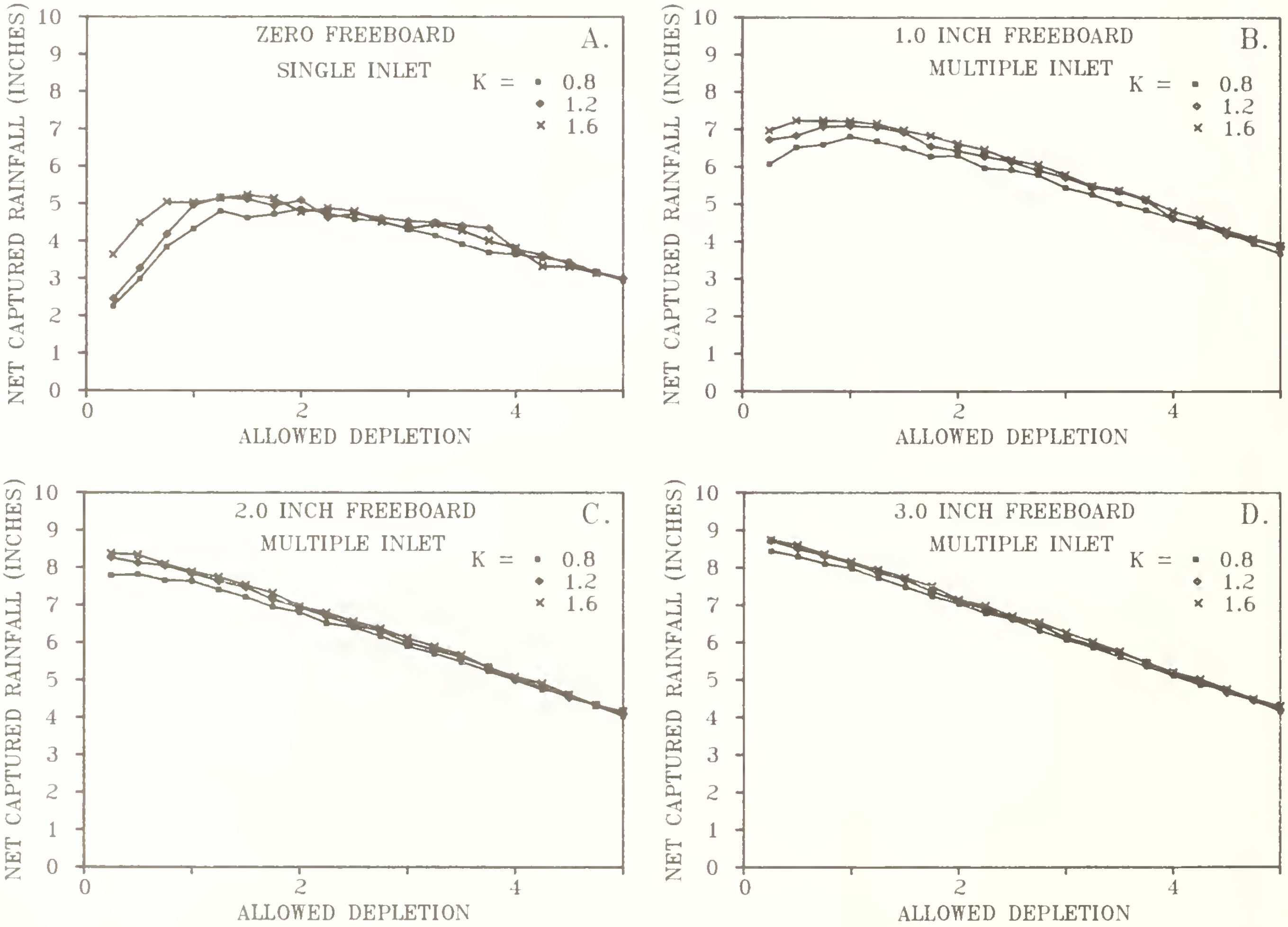

Figure 9. Net captured rainfall for range of allowed depletions for freeboards of (A) zero inches, (B) 1 inch, (C) 2 inches, and (D) 3 inches—each with three values of K from Equation 1.

pi Delta. With multiple inlets and 1 to 3 inches of freeboard remaining in the levees after all irrigations, the captured rainfall could be about 7 inches per season. Very precise water management would be required to approach these levels of rainfall capture and these modeled values should be considered as long-term maximum obtainable amounts, and probably would be greater than typical results for a large population of farm operations.

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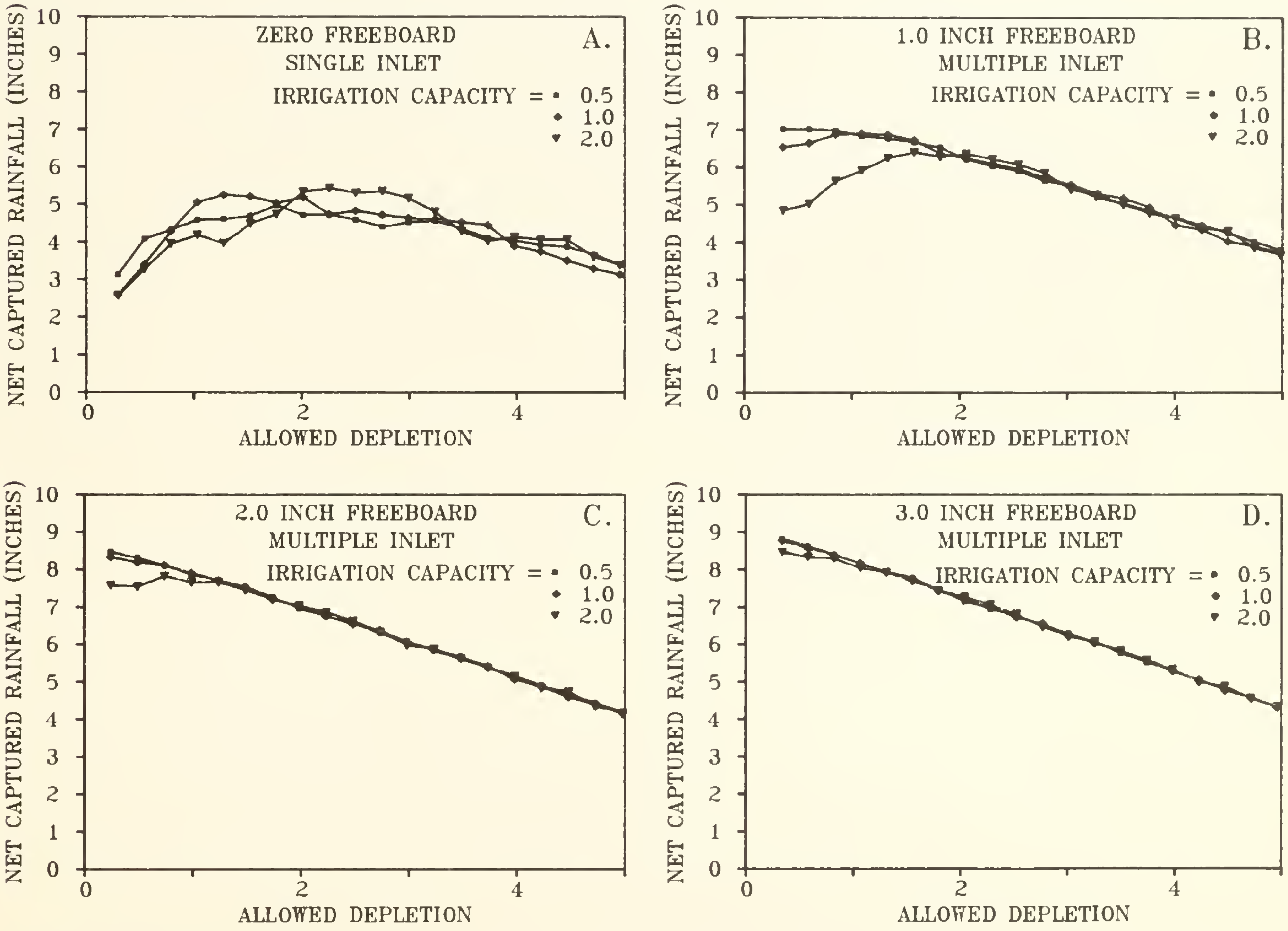

Figure 10. Net captured rainfall for range of allowed depletions for freeboards of (A) zero inches, (B) 1 inch, (C) 2 inches, and (D) 3 inches—each with three irrigation capacities (inches per day).

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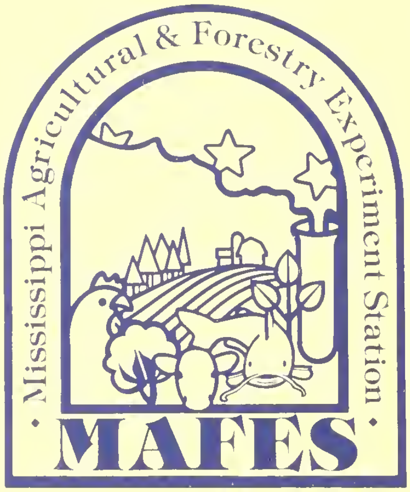
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PROGRESS

In Breeding Pecans for Disease Resistance

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Progress in Breeding Pecans for Disease Resistance

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Progress in Breeding Pecans for Disease Resistance

Introduction

Breeding for resistance to disease, with any tree crop, is historically time-consuming and costly. Thus, the initiation of a program with such a goal must be carefully planned, documented with basic understandings, and centered around the latest available plant breeding technologies. In recent years, we have been engaged in a program with the ultimate goal of developing cultivars of pecan [*Carya illinoensis* (Wangenheim) K. Koch.] with lasting resistance to the scab disease caused by *Cladosporium caryigenum* (Ell et Lang) Gottwald, but with several immediate goals. These include (1) definition of factors that may be associated with resistance, (2) identification of quality sources of resistance genes, and (3) development of procedures to expedite incorporation of these resistance genes into horticulturally desirable cultivars.

Consonant with these goals, an effort has been made to create at Mississippi State University a nursery collection of pecan x other hickory species (hicans), walnut x pecan, and pecan x pecan crosses involving only those parental genotypes deemed most promising for resistance breeding purposes. Present knowledge concerning resistance factors (particularly the phenolics believed important among resistance phenomena), known field resistance for parental choices, and breeding techniques have been utilized in developing this disease resistance breeding nursery. The purpose of this report is to detail progress in nursery development and to catalog the progeny contained in the Mississippi State University pecan disease resistance breeding nursery.

The Search for Resistance

C. caryigenum is known to have a great genetic diversity in nature and an operative mechanism for adaptive genetic reconstitution (1, 33). When one considers the adaptive capability of this fungus, and the range of fungal genotypes present across the pecan belt, the development of quality, lasting resistance in commercial pecan genotypes is a great challenge, most likely requiring the identification and transfer of resistance genes from hickory species other than *C. illinoensis*. We recognize that, in the past, cultivars thought to be resistant to scab later proved to be very

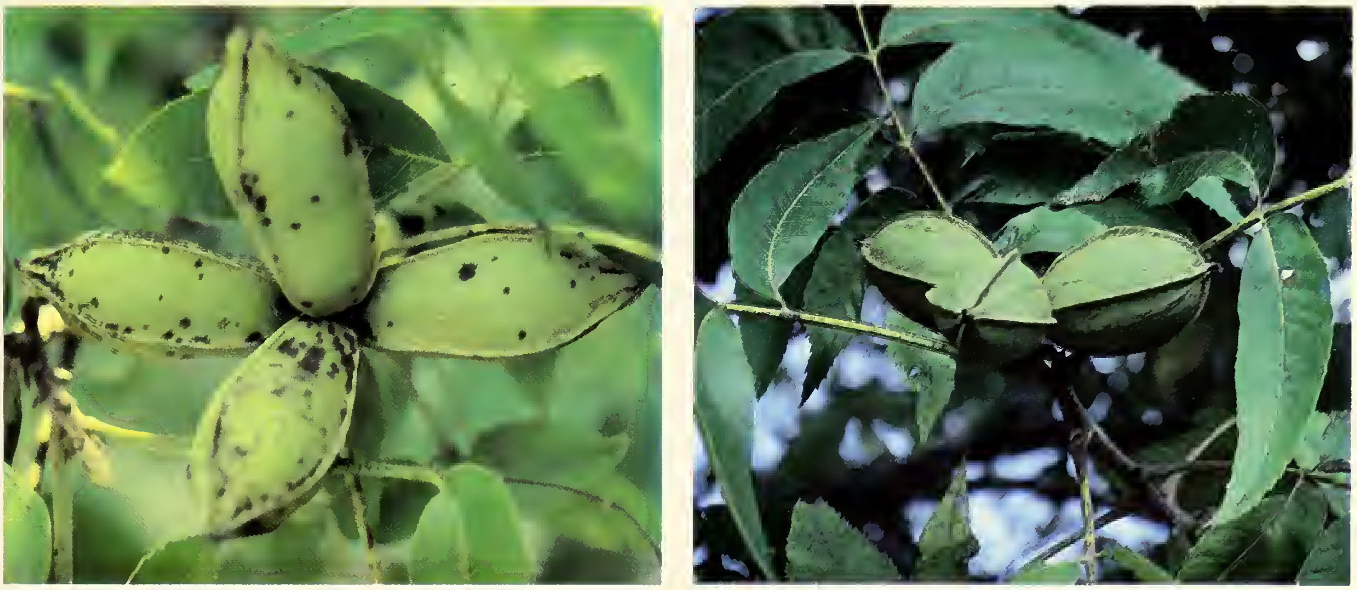


Figure 1. Pecan cluster at left shows symptoms of scab infection caused by *Cladosporium caryigenum* (Ell et Lang) Gottwald. In contrast, the cluster at right shows no signs of scab.

susceptible upon propagation and distribution. Kenknight (21), using scab inoculum from several sources, demonstrated infection on previously "non-scabbing" cultivars in Louisiana.

Street (35), at Mississippi State University, using a technique devised by McNeill (30) amenable to quarantine requirements and employing excised nuts, screened 25 pecan cultivars against 27 isolates of *C. caryigenum*. All cultivars except Baker were susceptible to one or more of the isolates. Minor infection also occurred upon Baker. Thus, once "non-scabbing" trees are vegetatively propagated and dispersed, the odds that the fungal genotypes capable of attacking them will increase prominently are greatly enhanced.

Observations (13) that native pecan populations often exhibit high levels of scab infection, whereas native stands of other hickory species rarely display such infection, suggest that these other species possess resistance factors not prevalent in pecan. Studies relative to resistance factors in pecan and other hickories at Mississippi State University seem to confirm this thesis, though these studies are not complete.

Juglone (5-hydroxy 1,4-naphthoquinone) has been shown to be a chemical host factor associated with resistance of pecan and other members of the Juglandaceae to scab (12, 18, 25). Juglone and hydrojuglone glucoside have also been correlated with resistance in juvenile leaves of black walnut (*Juglans nigra* L.) to anthracnose (*Gnomonia leptostyla* L.) (5).

In a survey of juglone levels in leaves and nuts, walnut trees (*Juglans regia* L. and *J. nigra*) possessed levels consistently higher than the hickories. Certain hickory trees were identified as having levels higher than those in pecans. Differences were noted among pecan cultivars (3). When juglone levels in husk, kernel, and leaflet of black walnut, shagbark hickory (*Carya ovata* (Mill) K. Koch), and four pecan cultivars were compared, the findings were: (husk) walnut > hickory and pecan; (leaflet) walnut > hickory and pecan; and (kernel) walnut > hickory > pecan (4).

Studies of seasonal variations of juglone content in pecan indicate that the level in leaves is higher in June, and decreases during the season. This decrease in leaves is accompanied by increases of juglone in nuts (4, 12, 18, 25). The leaf rachis, twigs, twig bark, trunk, root, root bark, and pollen all had notably lower levels of juglone than found in the leaves and nut tissues (4).

In addition to juglone, many plant phenolic derivatives have been implicated in disease resistance. The flavonoids, which include condensed tannins and isoquercitrin, comprise the largest class of phenolic compounds. Tannins in particular have been demonstrated to exhibit growth retardation of many parasites (7, 11) as well as feeding deterrents to insects and mammals (2, 16, 17, 26, 27, 39). Tannins are widely distributed in woody plants and are usually found in greatest concentration in epidermal tissues.

In 1982, Graves et al. (14) first demonstrated the fungitoxic effect of tannins extracted from pecan to *C. carigenum* at 4,000 ppm. Subsequently, concentrations of extractible tannins from leaves of the pecan cultivar Van Deman, ranging from 1,700 to 20,000 ppm, have been reported during the course of the growing season (14, 24). Recently, isoquercitrin has been identified in pecan tissue and found to be highly toxic to *C. caryigenum* (19, 22, 23).

Whereas the levels of juglone among pecan cultivars, hickory species, and walnuts have been studied, this has not been done for tannins or isoquercitrin. Cultivars of pecan and/or other hickory species may have differing levels of each phenolic compound. It is also possible that the differential capability of isolates to tolerate phenolic compounds may dictate isolate prevalence on a given host genotype. Further, the respective levels of each of these allelochemicals in combination may determine the quality of resistance.

To attribute disease resistance to chemical factors within host tissues requires more than identification of the factor and establishment of its antimicrobial activity *in vitro*. Considerations of concentration, location, and availability of chemicals in tissues invaded by the pathogen are equally important. Methods for histochemical localization and quantitation of the three principal phenolics in hickories have been developed (8, 9, 10, 15) and research is in progress to fully explore the potential role of phenolics in resistance to *C. caryigenum*.

Considering the time required in disease resistance breeding for a crop such as pecan, it was deemed expedient to begin a collection of pecan/walnut, pecan/hickory, pecan/hican, and pecan/pecan crosses useful in definitive studies, and as parental sources of quality disease resistance for future breeding efforts. It should be noted that progeny of these crosses may, upon evaluation, prove to be horticulturally desirable and useful genotypes for commercial exploitation.

Procedures

A program was begun in 1979 to create a collection of inter-and intraspecific crosses and backcrosses that could be useful for a concerted disease resistance breeding effort. Parental materials employed in the effort were as follows:

Female Parents

Stevens, Stuart, and Odom cultivars growing on the Mississippi State University campus were chosen as female parents. The logistics of effecting these crosses dictated that female parents must be conveniently located and accessible by a heavy lift truck that would permit making crosses near tops of the trees.

Stevens was chosen because of consistently high levels of juglone in leaves (highest of any pecans assayed), and levels near highest (among pecan cultivars) in fruit (3).

Stuart has scab resistance, good horticultural qualities, and became the most widely planted cultivar in the southeastern United States following its introduction in the 1920s. This cultivar exhibited good scab resistance throughout the southeast until the late 1950s when pockets of scab buildup became noticeable and significant. Scab has since become a problem on Stuart orchards in many areas. Even so, considering the extent of exposure by virtue of the extensive and widespread plantations, the length of time the Stuart cultivar remained scab-free, and the fact that scab is most often less severe where it does occur than on most cultivars, the presence of scab resistance qualities seems evident. It should also be noted that the juglone content in fruit of Stuart was near the highest, though in leaves it was very low (3).

Odom is also an old cultivar that has historically appeared relatively scab-free, although it is not widely planted. It also has exhibited a high level of juglone in both leaves and nuts in early studies (12).

Pollen Sources

From the beginning of the endeavor, an attempt was made to use pollens from as many different hickory and walnut species as possible, and from a representative number of hicans. Pecan cultivars of interest were also included where possible.

Pollen collection was limited by the availability of, and access to, catkin bearing trees, and our ability to collect catkins from trees at critical times. Critical periods for catkin harvest, to achieve successful pollen release, were usually less than 12 hours depending upon temperature, humidity, and wind conditions. Thus, daily inspections were necessary. These were often not possible with our resources, particularly when trees were located long distances from the campus. Pollen sources from which collections were obtained are listed in Table 1.

Breeding efforts were initiated with a pollination technique study in 1980-81 (37, 38). Methods deemed most appropriate as a result of this study were subsequently employed. Female flowers were protected by brown Kraft corn pollination bags (Lawson "Showerproof'd," No. 504). Bags were placed over wire hoops fastened with masking tape to the woody stem behind female flower clusters after catkin removal. The wire hoops were designed to prevent the pollination bags from collapsing on the foliage and flowers. Nonabsorbent cotton was wrapped around the stems and the bags were secured with masking tape to form a pollen proof seal.

Table 1. Pollen sources from which collections were obtained.

	Hickories other than pecan	
Nutmeg	*Carya myristicaeformis* (Michx.f.) Nutt	
Red	*C. ovalis* (Wangh.) Sarg.	
Common Shagbark	*C. ovata* (Mill) K. Koch	
Mockernut	*C. tomentosa* Nutt	
Pignut	*C. glabra* (Mill) Sweet	
Sand	*C. pallida* (Ashe) Engl.& Graebn	
Southern Shagbark	*C. carolinae-septentrionalis* (Ashe) Engl. & Graebn	
Water	*C. aquatica* (Michx.f.) Nutt	
Shellbark	*C. laciniosa* (Michx.f.) Loud.	
Bitternut	*C. cordiformis* (Wangh) K. Koch	
	Walnuts	
Black	*Juglans nigra* L.	
Persian (English)	*J. regia* L.	
	Hicans	
McCallister	(a natural cross of *C. illinoinsis* and *C. laciniosa*)	
Hican #1	(uncertain parentage)	
Hican #2	(uncertain parentage)	
	Pecan Cultivars	
Cape Fear	Moore	Pabst
Frotscher	Odom	Stevens
Lewis	Owens	Stuart

Pollens were collected by spreading mature catkins over aluminum foil in the laboratory. After 24 hours, the pollen was collected and filtered through two layers of cheese cloth to remove large pieces of trash. The pollen was stored in cotton stoppered vials and refrigerated or frozen until needed. Pollens to be used within 14 days of collection were placed in a dessicator and stored at 4°C. Those to be held for longer periods were placed in a dessicator and frozen at −20°C. Pollens released too late for use were held in a dessicator at −20°C and used the following year. Pollination was accomplished with a powder insufflator. A small hole was cut in the bags, the nozzle of the insufflator was inserted, and pollen was expelled in the vicinity of the flowers. Holes in the bags were sealed with masking tape. For controls, the entire procedure was repeated using an empty insufflator.

Bags and wire hoops were removed within 11 to 14 days after pollination. In August, the hoops were reattached to stems and plastic mesh bags were placed over the hoops to catch any nuts that might drop and to protect nuts from pests. Nuts, upon harvest, were carefully labelled, germinated, grown out in greenhouse culture and transplanted to a field nursery the following year.

Table 2. Inventory of progeny resulting from intra- and interspecific crosses within the Juglandaceae produced between 1980 and 1987 and currently being grown in a nursery located on the Mississippi State University Plant Science Research Center.

Male parent	Female parent	Total progeny
	Pecan x Pecan	
1. Cape Fear	Stuart	1
2. Frotscher	Stuart	2
3. Lewis	Stuart	3
4. Moore	Stuart	2
5. Odom	Stuart	3
6. Owens	Stuart	29
7. Pabst	Stuart	6
8. Stevens	Stuart	9
9. Stuart	Stuart	7
10. Cape Fear	Stevens	1
11. Frotscher	Stevens	26
12. Lewis	Stevens	4
13. Moore	Stevens	2
14. Owens	Stevens	6
15. Stevens	Stevens	5
16. Stuart	Stevens	25
17. Lewis	Odom	1
	TOTAL	132
	Other Hickories x Pecan	
1. Nutmeg	Stuart	6
2. Nutmeg	Stevens	3
3. Red Hickory	Stuart	3
4. Red Hickory	Stevens	9
5. Shagbark	Stuart	14
6. Shagbark	Stevens	2
7. Shagbark	Odom	2
8. Southern Shagbark	Stuart	4
9. Sand	Stuart	2
10. Sand	Odom	4
11. Mockernut	Stuart	4
12. Pignut	Stuart	5
	TOTAL	58
	Hican x Pecan Backcrosses	
1. McCallister	Stuart	14
2. McCallister	Stevens	2
3. Hican No. 2	Stevens	2
	TOTAL	18
	Intergeneric Crosses	
1. Black Walnut	Stuart	5
	TOTAL	5
GRAND TOTAL		213

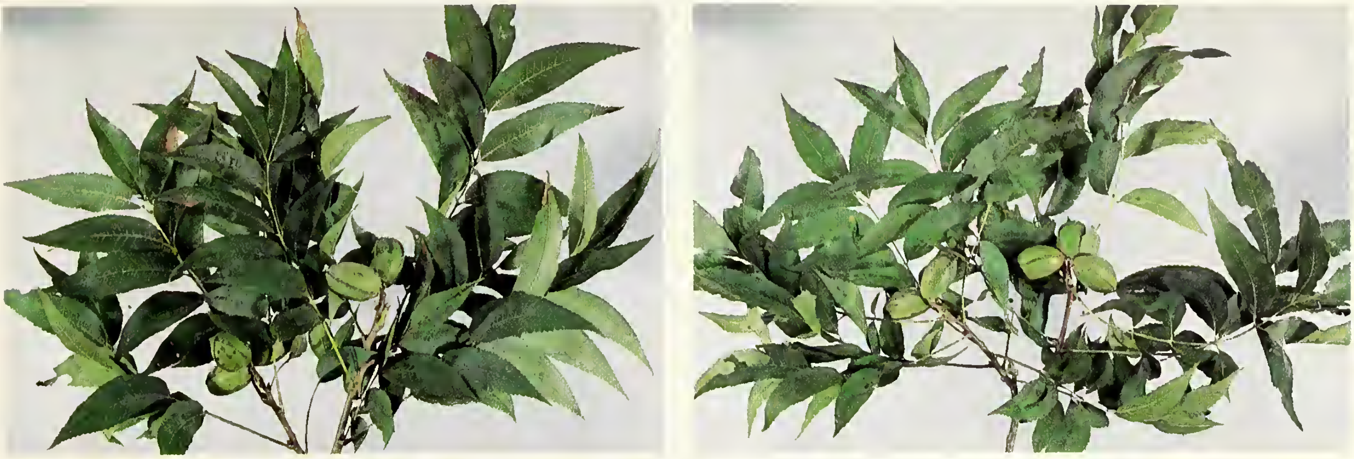
Subsequent to the pollination technique study completed in 1981 (37, 38), approximately 100 terminals were bagged each year through 1987. Successful crosses were achieved each year with the exception of one. Failures were thought to be related to improper timing.

Results and Discussion

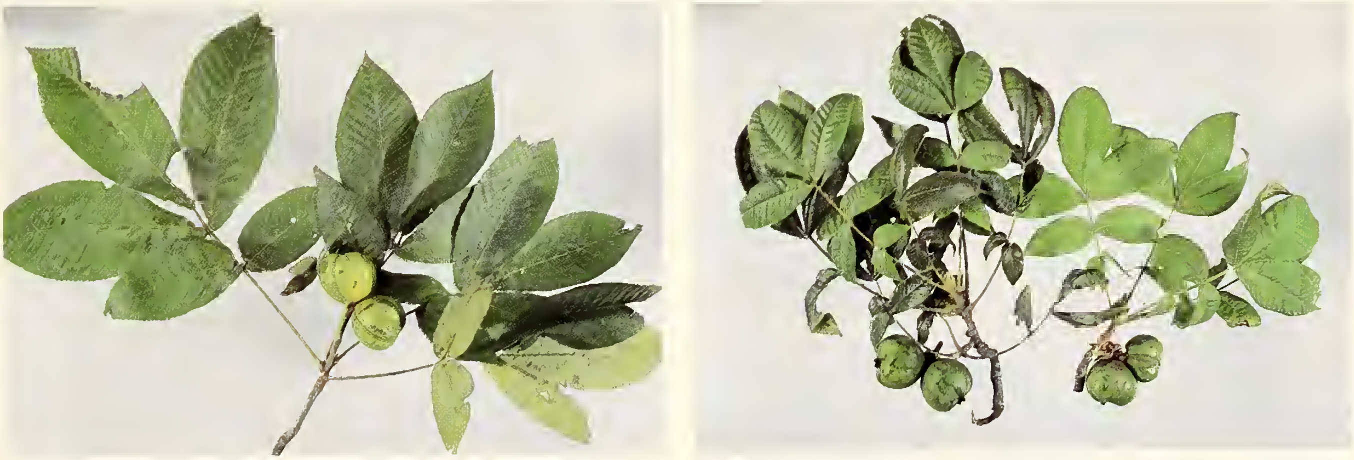
A total of 213 successful crosses were achieved during the course of the effort. The progeny are currently growing in a nursery located on the Mississippi State University Plant Science Research Center (Table 2). These include 132 intraspecific crosses, 58 interspecific crosses, 5 intergeneric crosses, and 18 hican x pecan crosses. Of these, 191 are currently large enough to harvest graftwood. The interspecific crosses include those with nutmeg [*Carya myristicaeformis* (Michx.f.) Nutt], red [*C. ovalis* (Wangh.) Sarg.], shagbark [*C. ovata* (Mill) K. Koch], southern shagbark [*C. carolinae-septentrionalis* (Ashe) Engl. & Graebn], sand [*C. pallida* (Ashe) Engl. & Graebn], mockernut [*C. tomentosa* Nutt], and pignut [*C. glabra* (Mill) Sweet]. Failure to achieve successful crosses with water [*C. aquatica* (Michx.f.) Nutt], shellbark [*C. laciniosa* (Michx.f.) Loud.], and bitternut [*C. cordiformis* (Wangh) K. Koch] most likely had nothing to do with compatibility, but rather, difficulties in obtaining viable pollens, and the timing of pollination. A particular disappointment was our failure to produce progeny from the shellbark x pecan cross. We believe this cross has great promise. Unfortunately, harvests from our pollen sources were difficult. We also had difficulty obtaining adequate pollen from our hican sources, because all were located more than 100 miles from campus. We obtained a good harvest from the McCallister hican on one occasion. The McCallister pollen stored well and some successes were achieved the following year using frozen pollen.

Plans are to continue attempts to broaden our collection of interspecific crosses, and to compare these to parental types in our efforts to understand resistance phenomena. These will be compared as to levels of the individual phenolics, and the relationships of these to infection phenomena with *C. caryigenum*. The methods of Diehl et al. (8, 9, 10) and Graves et al. (15); involving histochemical quantitation at the infection site, scanning and transmission electron microscopy, and confirmatory immunoflourescent procedures, will be used for genotypic comparisons. Information from such studies should provide insight in parental choices for resistance breeding purposes, as well as guidance as to inheritance of resistance factors. Isozyme methodologies

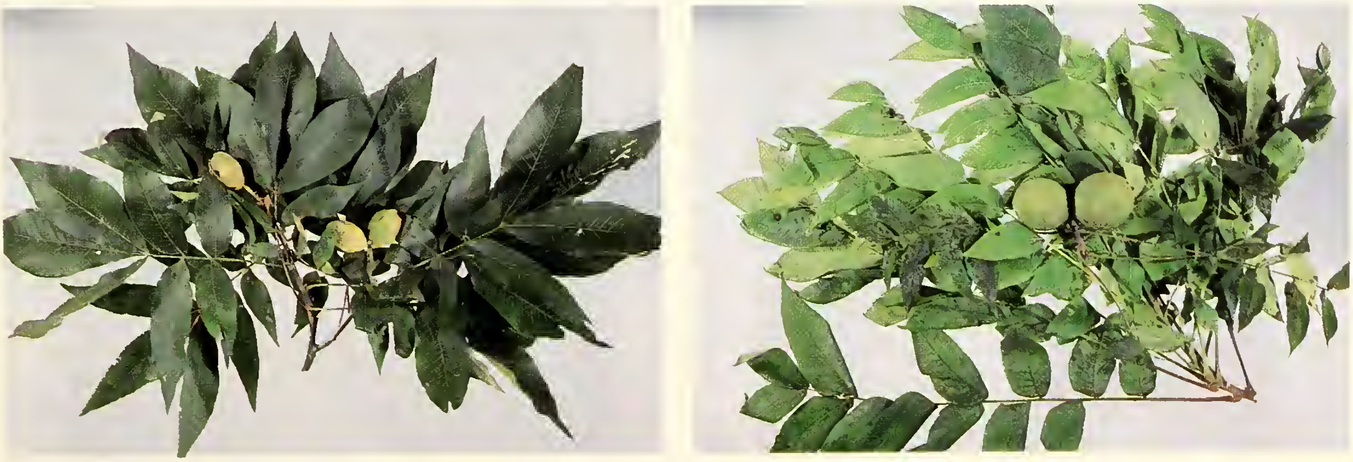
Figure 2. Photographs of some of the major pecan cultivars and hickory and walnut species used in crosses to develop scab resistance in pecan.



Stuart Pecan *Odom Pecan*



Shagbark hickory *Sand hickory*



Nutmeg hickory *Black Walnut*

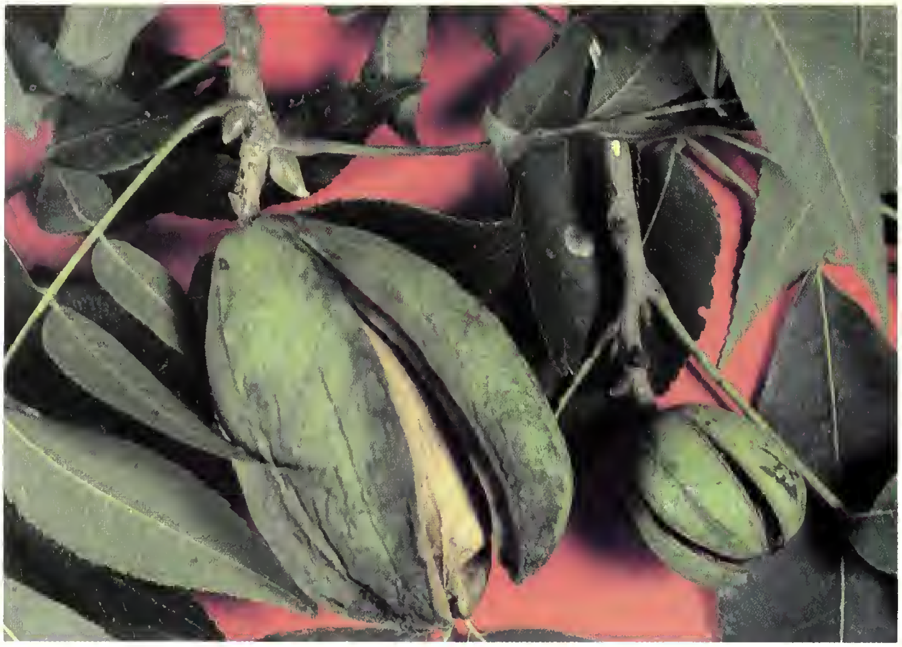


Figure 3. At left is the large McCallister hican harvested from an orchard near Yazoo City, MS. It is more than twice the size of the Stuart pecan on the right.

will be developed to confirm genotypic verity of individual crosses, and as a tool in further breeding work in following inheritance of identifiable resistance factors.

There have been several reports of natural hybrids resulting from crosses between pecan and a number of other hickory species including water (34), shellbark, mockernut, bitternut (32), and shagbark (6). Additionally, there have been various reports from controlled crosses (20, 28, 29, 36), not to mention verbal reports of hobbiests and growers. This is perhaps the first report of controlled crosses of pecan x nutmeg, red, southern shagbark, sand, and pignut hickories. It is perhaps also the first report of controlled crosses of pecan x black walnut. The hican x pecan backcrosses represent an interesting first step since it is believed that such backcrosses offer the best prospect for introducing improved disease resistance into progeny with acceptable fruit quality.

Most hickories (including pecan) have a somatic chromosome number of 32. Some, such as pignut, red, sand, and mockernut, are tetraploids with a chromosome number of 64 (20). Natural crosses between diploids and tetraploids have been reported (31, 32). The resulting triploids are sterile. It is theoretically possible to create fertile hybrids from such crosses by doubling the chromosome number using colchiploidy techniques, or perhaps by genetic manipulations that may someday be possible should success be made in achieving somatic embryogenesis through tissue culture methods.

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Perennial Vine Competition & Control

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Perennial Vine Competition and Control

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Perennial Vine Competition and Control

Introduction

Perennial vines are serious weed pests of cultivated crops in Mississippi (5). Two common perennial vines found in the Delta and elsewhere in the state are redvine (*Brunnichia ovata* (Walt.) Shinners) and trumpetcreeper (*Campsis radicans* (L.) Seem.) (4). Less common but also present are honeyvine milkweed (*Ampalamus albidus* (Nutt.) Britt.), maypop passionflower (*passiflora incarnat*a L.), and redberry moonseed (*Cocculus carolinus* (L.) DC). These are all dicots in different families, but with many common features as weeds in our crops. Each is deciduous, woody, and capable of regeneration from deeply positioned rootstocks in cultivated fields. Redvine (see drawing on page 6) seems to be confined mainly to fine-textured soils (4, 8), but trumpetcreeper (see drawing page 5 and cover) and other perennial vines apparently are not restricted to soil type for their habitat. They occur in all crops and situations in cultivated agriculture in Mississippi, although flooding may limit interference in rice.

These perennial weeds, when present, may not measurably interfere with crop yield to any large extent (8). In a 3-year study on redvine in cotton, Hurst et al. (8) were not able to show an effect on cotton yield. Others (2, 9, 10, 12) have reported on efforts to control these vines but have not reported the interference effect of these vines. The implication of their reports is that they do interfere with cultural practices and harvest operations.

Herbicides and techniques for control of these perennial vines are limited (2, 3, 8, 9, 10, 11, 12, 13). Few methods or herbicides have been found that will control the weeds, and even fewer have sufficient selectivity to be used in a crop situation. The phenoxys and dicamba (3) have some activity on these plants, but are lacking in crop selectivity at the rate required for control. Glyphosate (10, 14) has also been found to be effective on these weeds, but has virtually no crop selectivity.

A method that has been suggested to achieve control without consequent crop injury is to apply the herbicide (dicamba or glyphosate) to a fallowed field or other situation when the crop is not present or will not be harmed (2, 3, 8). In such a scheme, the herbicide (dicamba or glyphosate) is applied after harvest, or, in the case of cotton (*Gossypium hirsutum* L.) (8), after defoliation but before a killing frost has occurred. In soybean, however, harvest of the crop removes most of the weed foliage and there is little left for the herbicide to interact with. Unless there is time for the vegetation to regrow between harvest and frost, such a scheme has little chance of success in soybean. Applying the herbicide to mature soybean is not labeled. Preplant applications of dicamba result in crop injury, while application of glyphosate to these weeds in the spring is generally not successful (10).

Our objective was to determine if a natural population of perennial vines, including redvine, trumpetcreeper, redberry moonseed, maypop passionflower, and honeyvine milkweek, could be controlled using potential technology (dicamba in the fall), and, if so, if the control would have any effect on crop yield.

Materials and Methods

General

The study was conducted during 1983-1987 on a Tunica clay (clayey over loamy, montmorillonitic, nonacid, thermic, Vertic Haplaquept) near Stoneville, MS. Two adjacent areas were designated for the dual experiment; one for dryland, non-irrigated production, and one for irrigated production. All plots were eight 40-inch rows, 100 feet long. The design was a split-plot with three treatments and four replicates in both the irrigated and non-irrigated experiments. Data for each crop were analyzed separately for each year and each irrigation regime.

The main plots were three rotation cropping schemes, while the sub-plot was with or without dicamba. The three rotations were continuous cycles of (1) wheat-soybean doublecropping; (2) corn followed by wheat-soybean doublecropping; and (3) grain sorghum followed by wheat-soybean doublecropping. The experiment began Oct. 7, 1983, when dicamba was applied at 2.0 pound ai/acre for control of a natural population of perennial vines consisting of redvine, trumpetcreeper, honeyvine milkweed, redberry moonseed, and maypop passionflower. Ten days after treatment, the land was prepared for planting. Corn and sorghum plots were bedded and left over winter. Southern Belle wheat was planted Oct. 18, 1983, at 90 pounds/acre in the wheat-soybean doublecropping treatment. Only the untreated wheat plots were harvested since this rate of dicamba adversely affects wheat.

Conventionally accepted cultural practices that promote high production expectations were utilized for each crop each year. Cultivar selection, seeding rate, fertilization, and pest control were applied as required for high yields. The only essential difference between the two experiments was the use of irrigation in the irrigated experiment. A full weed control program was effectively used, but the herbicides generally do not have an effect on the perennial vines. Table 1 lists the herbicides used each year.

The cultivars used were: corn, Pioneer 3160 in 1984 and Pioneer 3147 in 1986; sorghum, Funk's G-522DR in 1984 and Pioneer 8333 in 1986; soybean, Centennial in 1984 and 1985, Braxton in 1986, and Asgrow 5980 in 1987; wheat, Southern Belle in 1983, Coker 916 in 1984, and Florida 302 in 1985 and 1986.

Weed sampling

Weeds were sampled in each plot prior to harvest, and sampling was similar to previous efforts (6). A visual estimate by species of percentage ground cover was obtained by randomly locating twenty 5.4 ft^2 quadrates in each plot. If a species was in the plot but not in any quadrate, then it was listed as present but no ground cover value was assigned. No weed estimates were obtained for the wheat crop.

Statistical analysis

Analyses for weed cover of the perennial vines were combined where appropriate. The standard error of the mean (SE) for each measured variable was calculated.

A combined analysis of variance over years was computed which considered the two experiments as separate locations. Since the plot assignment remained intact for the duration of the experiment, years are simply repeated measurements in the same experiment. As in separate locations, no statistical test can be made of the location (irrigation) effect. However, interaction effects involving irrigation are subject to F Test.

Results and Discussion

A combined analysis over years for the weed cover of perennial vines showed no effect of years or any interaction of any effect with years. Therefore, the data in Table 2 are presented as the mean over years of the combined experiments. Dicamba applied once in the fall of 1983 suppressed perennial vines for 4 years (Table 2). The suppression was not complete, nor was it equal in all crops. Soybeans with full canopies from irrigation or suitable dryland conditions had less perennial vine ground cover. In corn, there were more perennial vines, especially in the non-irrigated experi-

Table 1. Herbicide application to the three wheat-soybean rotation crops.

	Cropping System[a]		
Input	**Wheat-soybean**	**Corn, wheat-soybean**	**Sorghum, wheat-soybean**
		1984 Crop Year	
Preemergence	Metribuzin plus metolachlor	Atrazine plus alachlor	metolachlor plus cyanazine
Postemergence	Bentazon plus acifluorfen, fluazifop (spot) 2,4-DB plus linuron layby)	None	None
		1985 Crop Year	
Preemergence	Metribuzin plus metolachlor	Metribuzin plus metolachlor	Metribuzin plus metolachlor
Postemergence	As in 1984	As in 1984 (Soy)	As in 1984 (Soy)
		1986 Crop Year	
Preemergence	Metribuzin plus metolachlor	Atrazine plus alachlor	Metolachlor plus cyanazine
Postemergence	fluazifop (spot), 2, 4-DB plus linuron (layby)	None	None
		1987 Crop Year	
Preemergence	Metribuzin plus metolachlor	Metribuzin plus metolachlor	Metribuzin plus metolachlor
Postemergence	As in 1986	As in 1986 (Soy)	As in 1986 (Soy)

[a] All herbicides were used at the recommended label rate for the given crop and soil type.

Table 2. Effect of dicamba on total weeds and perennial vines in the irrigated and non-irrigated experiments in the three crop systems averaged over 4 years.

		Cropping System[a]					
		W-S[c]		C, W-S		S, W-S	
Irrigation	Dicamba[b]	Total[d]	PV	Total	PV	Total	PV
		(% ground cover)					
With	With	2.6	0.6	7.6	1.2	4.1	0.8
	Without	3.5	1.9	19.2	11.9	14.4	10.4
Without	With	5.7	3.3	15.2	9.7	9.2	4.6
	Without	21.3	19.5	41.3	32.9	28.0	25.1

[a] Cropping Systems are: W-S = wheat-soybean doublecropping; C,W-S = corn followed by W-S; S, W-S = sorghum W-S.

[b] LSD for the difference between two dicamba means within a cropping system treatment and irrigation is 2.5 and 2.1 for total and PV, respectively.

[c] LSD for the difference between two treatment means within a dicamba treatment and irrigation is 3.0 and 2.5 for total and PV, respectively.

[d] Total is the total weed cover, PV is the perennial vine weed cover.

ment. This is probably related to the open canopy structure of the crop since a wide (40-inch) row spacing was used. Values for perennial vine ground cover in sorghum were intermediate between those for corn when irrigation was used.

Ground cover from the total weed spectrum (including the perennial vines) was different between dicamba treatments and among crops (Table 2), but this was totally a reflection of the dicamba effect on the perennial vines (data not presented). Corn had significantly more weeds than the other two crops, as was noted for the perennial vines in Table 2. These weed cover values were taken just prior to harvest and may not accurately reflect the interference value for corn. Many of the perennial weeds in corn were reaching their full effect at corn harvest time (mid-August), while the other crops were still green and fully canopied. There was no suggestion that the dicamba had a residual effect on weed control other than its effect on the perennial vines noted in Table 2.

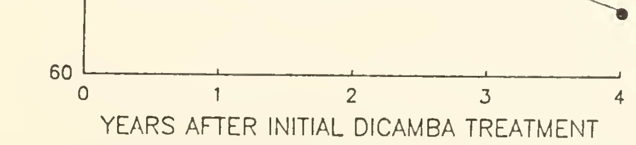

Figure 1. Comparison of vine suppression achieved for 4 years following application of dicamba for control of redvine and trumpetcreeper.

Dicamba was not equally effective on vine species (Figure 1). Redvine was apparently reduced more (but not significantly) than trumpetcreeper. Since this was a natural population, the distribution of the vines was not uniform over the study area. However, redvine was more prevalent over the whole study than the other vine species. Perennial weeds tend to grow in small concentrated areas making statistical calculations and conclusions difficult. Even so, the data are conclusive that dicamba can effectively result in vine suppression.

In 1984, there was no effect of dicamba treatment on yield of any crop (Table 3). In 1985, when all rotations were in the soybean sequence, there was an apparent advantage for the dicamba treatment, especially in the irrigated and non-irrigated corn, wheat-soybean system. Without irrigation the average advantage was 5 bushels/acre and with irrigation it was 4 bushels/acre. In 1986, only yield of corn was affected by the dicamba application, with 7 and 11 bushels/acre increases in the non-irrigated and irrigated experiments, respectively. In 1987, a soybean sequence year, the dicamba-treated plots had higher yields than the untreated plots by 1.5 bushels/acre in the non-irrigated and 6.5 bushels/acre in the irrigated experiments. Interestingly, the soybean yield differences in the continuous wheat-soybean doublecrop treatment are lower than those in the rotated treatment in either the irrigated or non-irrigated experiments of any year. This suggests that in order to more efficiently determine yield differences, the system should not be under any other yield limiting factor. Rotations, early planting, and irrigation are known to improve soybean yield (7).

Cultivar and hybrid selection varied throughout the experiment from year to year in each of the crops. These results were not intended to compare years with each other, but rather to develop agronomic performance information with the best possible current-

Table 3. Yield of crops in three rotation systems in irrigated and non-irrigated experiments as affected by dicamba application.

			Cropping System[a]				
			W-S	C, W-S		S, W-S	
Irrigation	Year	Dicamba	Soybean	Corn	Soybean	Sorghum	Soybean
			bu/ac				
With	1984	With	38	100		110	
		Without	38	101		103	
	1985	With	38		43		42[d]
		Without	36		38		39[e]
	1986	With	31	128[c]		_[b]	
		Without	32	117[c]		_[b]	
	1987	With	21		37		36
		Without	20		30		30
Without	1984	With	9	43		78	
		Without	9	43		80	
	1985	With	21		29		31
		Without	18		23		29
	1986	With	1	83[c]		_[b]	
		Without	1	76[c]		_[b]	
	1987	With	2		7		7
		Without	1		4		7

[a] Yield of the wheat crop is not reported. S = soybean in W-S and in 1985 and 1987 all yields are soybean. In 1984 and 1986 the yields are for corn and sorghum in their respective rotations.

[b] Yield not determined because of Midge damage to sorghum.

[c] SE for these corn means is 3.0 bu/acre. The other corn and sorghum NS.

[d] LSD for dicamba effect on soybean yield within a cropping system and irrigation in 1985 is 2.1 and in 1987 is 1.0 bu/acre.

[e] LSD for cropping system effect on soybean yield within a dicamba and irrigation treatment is 2.5 in 1985 and 1.2 bu/acre in 1987.

selections. We feel that any comparisons of treatment effect would be valid with any high performing cultivar or hybrid. We have no information to suggest that cultivar or hybrid selection had any effect on the yield performance comparison between dicamba-treated plots in any year. The corn hybrid was changed to get a better selection for the clay soil, and to get the most current hybrid possible. This was also true for the sorghum hybrid and wheat cultivar selections.

For the soybeans in 1984, 1985, and 1986, we used Maturity Group VI cultivars since this was the conventional practice. Soybeans planted after wheat require a late maturing cultivar to develop sufficiently to produce a good yield. We used different cultivars, but they were within the same maturity group. In 1987, we changed to a Maturity Group V cultivar. Our thinking was that this would allow us the time in the fall to harvest the soybeans and plant wheat or prepare a seedbed for the corn or sorghum. Also, the performance of the chosen cultivar was adequate for this situation. Again, our results are not to be compared over years but within a year.

These results suggest that any effect that the vines have on crop growth and yield is not consistent over time even with the similar levels of vine presence. This has been the finding of others who have investigated the effect of perennial vine presence on crop yield (8). Any recommendation concerning the use of this herbicide for control of the vines should be mindful of the apparent inconsistencies in yield response. However, the cost of having the vines present and the effect on harvest efficiency and quality of the harvested product (foreign matter or moisture) has not been documented. Lack of documentation has not deterred producers, however. Vine presence does adversely affect field operations. We have experienced vine-clogged combines and difficulties in cultivating as well, but have no data on any of these factors. Vines in fields are unsightly, can affect field operations to an unknown extent, and can affect yields, especially in soybeans that have a high yield potential, such as following corn or sorghum with irrigation. All of these factors should be considered when contemplating an attempt to control these weeds.

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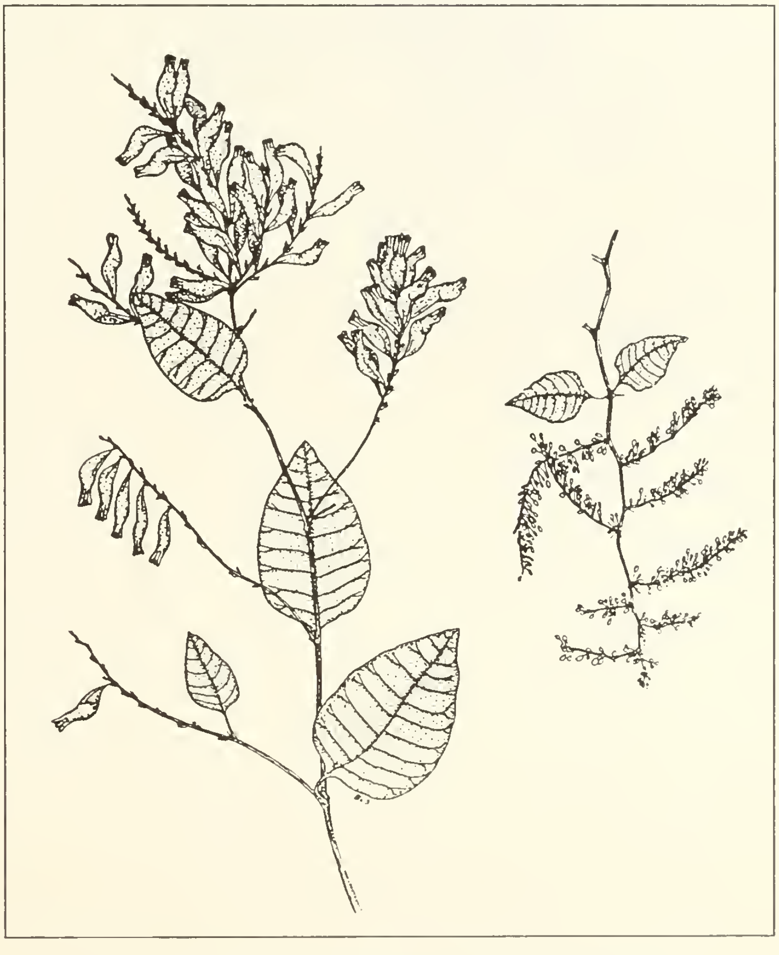
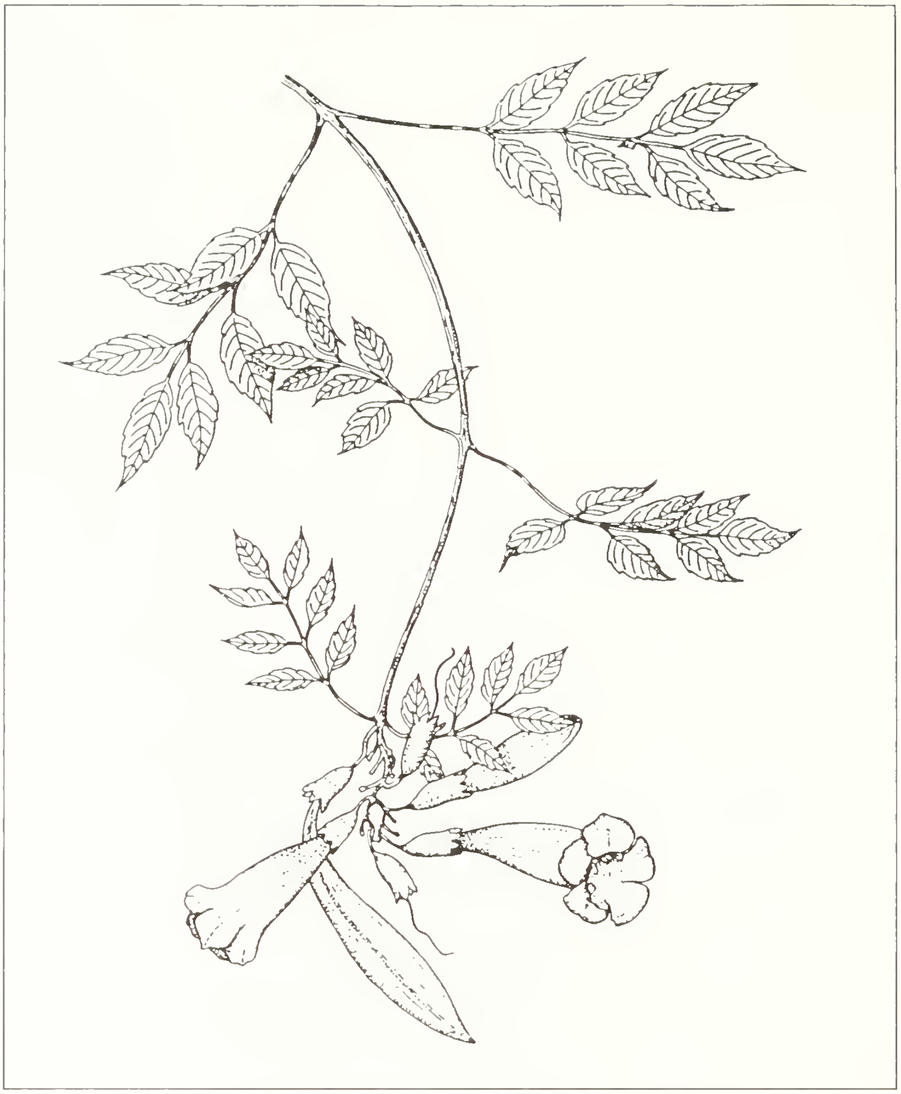


Drawing of redvine (*Brunnichia ovata* (Walt.) Shinners].



Drawing of trumpetcreeper [*Campsis radicans* (L.) Seem].

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SOCIOECONOMIC CONDITIONS:

The Mississippi Delta

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Socioeconomic Conditions: The Mississippi Delta

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Contents

Page

INTRODUCTION 1

STUDY AREA 3

DEMOGRAPHIC CHARACTERISTICS 4

ECONOMIC STRUCTURE 5
- Personal Income Components 5
- Industrial Base Components 6
- Goods Producing Sectors 7
- Services Producing Sectors 9
- Farming and Farm-related Sectors 9
- Farm Sector Characteristics 10

INCOME 11

COMPARING THE DELTA STUDY AREAS 12
- *Central Nonmetro* Delta 12
- *Fringe Nonmetro* Delta 12
- *Metropolitan* Delta Counties 13

IMPLICATIONS 13

REFERENCES 14

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Socioeconomic Conditions: The Mississippi Delta

Lynn Reinschmiedt and Bernal Green

Introduction

The economic plight of rural America has undergone renewed appraisal in relation to that of the nation's metropolitan areas. This has been due in part to the farm crisis of the 1980s, and faltering of the widely publicized rural turn-around of the 1970s. This so-called "rural renaissance" was short-lived and was not equitably distributed. The Commission on the Future of the South recognized this in its report, *Halfway Home and A Long Way To Go*, when it concluded that the widely publicized new jobs created in the South during the 1970s were largely claimed by educated, urban middle-class Southerners (p.5).

Two recent publications have addressed the breadth of the problems facing rural America and the prospects for future rural economic development initiatives (Brown et al., 1988; U.S. Congress, 1986). Deavers' comment (p.384) that ". . .the economic and social setting in rural America that shapes future policy decisions is one of widespread stagnation in job creation, reduced rates of population growth, and substantial outmigration" reflects the situation facing rural residents and policymakers regarding rural America.

Rural America is in transition, attempting to adapt to a dynamic domestic and global economy. Structural changes in the rural economy have resulted in economic dislocation of the resource base, particularly human resources through lost job opportunities and migration. Structural change and its related impacts test the ability of rural communities to adapt and meet the economic and social challenges of the 1990s and beyond. Meeting these challenges will involve rural economic policies that emphasize human resource development and job creation for displaced workers as well as new entrants into the work force (Brown and Deavers, 1988).

The improvement of education was the one overwhelming priority voiced by participants in the southeastern regional "Rural Development Policy Options Workshop" held in Birmingham, Alabama in 1988. Job creation, infrastructure, local rural leadership, and other related issues were important as well, but it was clear that education was a necessary condition for these other developmental components to foster sustained success (Knutson and Fisher, 1989).

Prior to developing a set of policies to address rural development needs, information on socioeconomic conditions of rural areas is important. Such information should document the current socioeconomic structure and the changes that have occurred in that structure.

This report examines the socioeconomic conditions of the Mississippi River Delta region that has historically had a disproportionate share of poverty and has lagged behind the rest of the nation in its economic development. So distressed are the economic conditions in this region that the 100th U.S. Congress passed the *Lower Mississippi Delta Development Act* in 1988, establishing a commission to study and make recommendations regarding economic development needs of the Lower Mississippi Delta region (U.S. Congress, 1988).

A comparative statics approach is used to document the socioeconomic conditions of the Mississippi River Delta region as defined in the *Lower Mississippi Delta Development Act*. While this analysis broadly addresses the socioeconomic structure of the study area, it should aid policymakers in targeting policies and assistance in areas of greatest need.

The report is organized in the following manner. The Mississippi River Delta counties that constitute the study area are identified and their socio-demographic and economic structures are addressed. The socio-demographic study focuses on population characteristics and measures of well-being, while the economic analysis looks at personal income components, industrial base components, goods and services sectors, and the farming sector. A more detailed examination of income levels and sources of income is then presented, followed by a broad-based comparison of the study regions and a consideration of policy options.

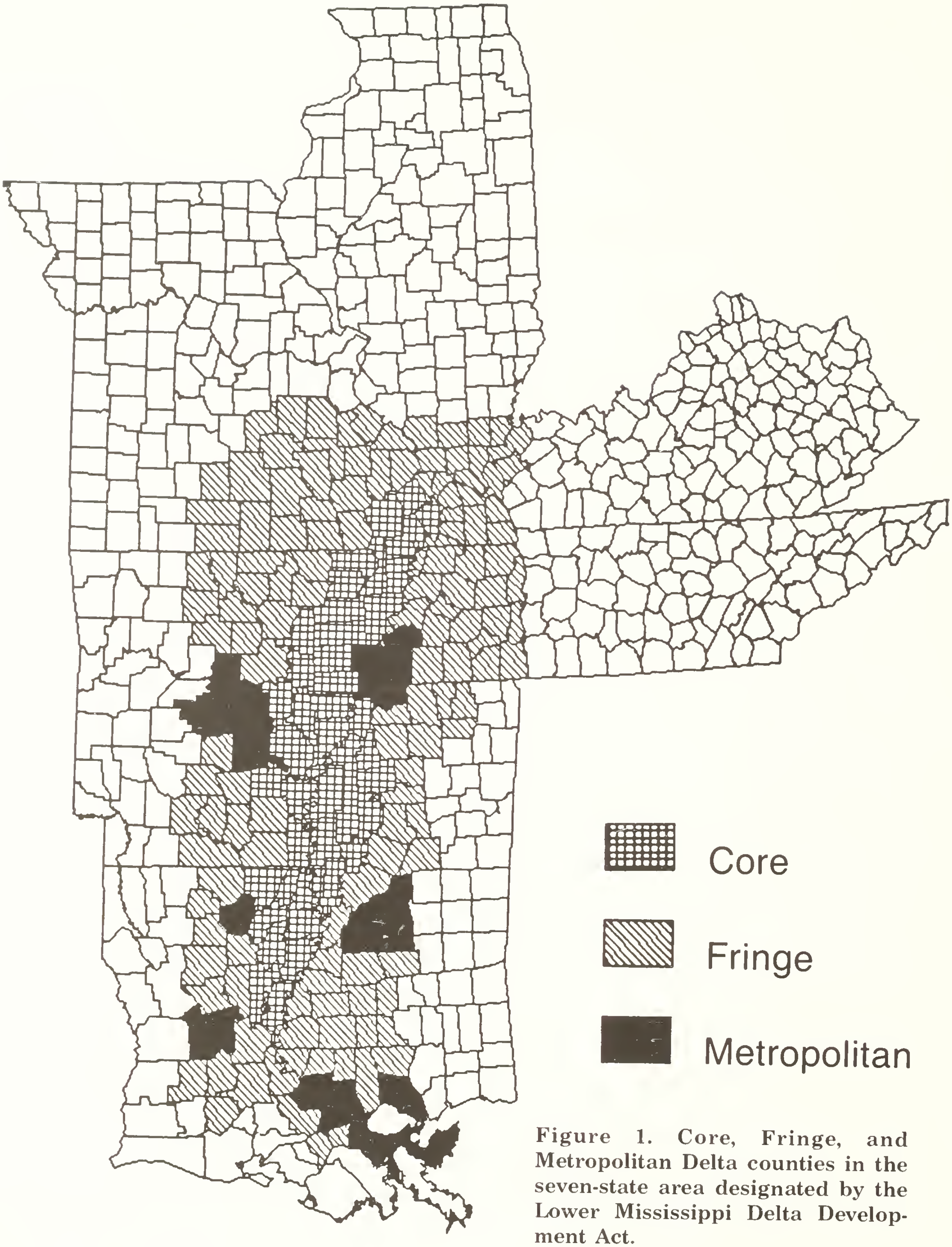
▦ Core
▨ Fringe
■ Metropolitan

Figure 1. Core, Fringe, and Metropolitan Delta counties in the seven-state area designated by the Lower Mississippi Delta Development Act.

Study Area

The *Lower Mississippi Delta Development Act* defines "Lower Mississippi" as "those areas within a reasonable proximity of the Mississippi River in Arkansas, southern Illinois, western Kentucky, Louisiana, Mississippi, southeastern Missouri, and western Tennessee." Furthermore, it states that the "Delta" should include such areas that "share common economic, social, and cultural ties, . . ." (U.S. Congress, 1988). In all, the initial legislation designated 186 counties as part of the Delta. Such a definition, however, obscures differences in physiographic and socioeconomic characteristics inherent in the geographic areas defined by the alluvial floodplain of the Mississippi River and the more broadly defined areas specified in the Act.

Recognizing the potential for significant differences across the 186 Delta counties, this study partitions the Delta into sub-regions descriptive of geographic location and/or degree of urban development. First, an area closely analogous to Crecink and Steptoe's definition of the Delta, which extended from the Bootheel area of Missouri to the Red River in Louisiana, was designated as the *Central* Delta region, and includes the 43 nonmetro Delta counties lying entirely within the flatland Delta region in Arkansas, Louisiana, Mississippi, and Missouri (Figure 1).[1] Secondly, the 134 counties in the seven-state area identified by the Lower Mississippi Economic Development Act, which lie beyond the geographic confines of the Central region and are not metropolitan areas, were designated the *Fringe Delta.*[2] Taken together, the nonmetro *Central* and *Fringe* areas make up the 177 *nonmetro* Delta counties. A third sub-category (Figure 1) consists of the 24 metropolitan counties.[3] Not all of these counties were identified in the initial legislation, but were added to this analysis either because they were embedded in the contiguous county areas or were adjacent to the Delta region.

Because of differences in size of the metropolitan areas, one metro group containing counties in the New Orleans and Memphis metropolitan areas, and another representing all other metro areas, were identified. Additionally, all the previously described subgroups in aggregate were classified as *All* Delta and included a total of 199 counties. All 653 counties in the seven-state area were used as a benchmark for comparison. These Delta delineations should provide for relevant comparisons of the socioeconomic and demographic variables that will be used to describe the Delta and provide needed information for policy development.

---

[1] The states and counties in the *Central* Delta include:

Arkansas: Arkansas, Chicot, Clay, Craighead, Cross, Desha, Greene, Jackson, Lee, Lincoln, Mississippi, Monroe, Phillips, Poinsett, Prairie, St. Francis, and Woodruff.

Louisiana: Catahoula, Concordia, East Carroll, Franklin, Madison, Morehouse, Richland, Tensas, and West Carroll.

Mississippi: Bolivar, Coahoma, Humphreys, Issaquena, Leflore, Quitman, Sharkey, Sunflower, Tallahatchie, Tunica, and Washington.

Missouri: Dunklin, Mississippi, New Madrid, Pemiscot, Scott, and Stoddard.

[2] The states and counties in the Fringe Delta include:

Arkansas: Ashley, Drew, Bradley, Union, Cleveland, Calhoun, Lawrence, Randolph, White, Independence, Sharp, Ouachita, Dallas, Grant, Fulton, Izard, Stone, Searcy, Marion, Van Buren, and Baxter.

Louisiana: Union, Lincoln, Jackson, Caldwell, Winn, Grant, LaSalle, Avoyelles, Pointe Coupee, St Landry, West Feliciana, East Feliciana, St Helena, Tangipahoa, Iberville, Assumption, Washington, Allen, Evangeline, Acadia, and St James.

Mississippi: Tate, Marshall, Benton, Tippah, Union, Panola, Lafayette, Yalobusha, Holmes, Grenada, Carroll, Montgomery, Yazoo, Warren, Attala, Claiborne, Copiah, Jefferson, Adams, Lincoln, Pike, Amite, Wilkinson, Franklin, Simpson, Lawrence, and Walthall.

Missouri: Butler, Ripley, Carter, Wayne, Bollinger, Cape Girardeau, Oregon, Shannon, Reynolds, Iron, Madison, Perry, St Genevieve, St Francois, Washington, Crawford, Dent, Texas, Howell, Ozark, Douglas, Wright, and Phelps.

Tennessee: Lauderdale, Dyer, Obion, Fayette, Crockett, Haywood, Hardeman, McNiry, Hardin, Chester, Gibson, Weakley, Henry, Carroll, Madison, Decatur, Benton, Lake, and Henderson.

Kentucky: Ballard, Calloway, Carlisle, Crittenden, Fulton, Graves, Hickman, Livingston, McCracken, Marshall, and Union.

Illinois: Alexander, Gallatin, Hardin, Jackson, Johnson, Massac, Pope, Pulaski, Saline, Union, and Williamson.

[3] The metropolitan Delta county designations include:

DELTA

Arkansas: Crittenden (West Memphis) and Jefferson (Pine Bluff).

NON-DELTA

Arkansas: Pulaski (Little Rock), Faulkner (Little Rock), Lonoke (Little Rock), Saline (Little Rock).

Mississippi: Hinds (Jackson), Madison (Jackson), Rankin (Jackson).

Louisiana: Ouachita (Monroe), Rapides (Alexan dria), East Baton Rouge (Baton Rouge), West Baton Rouge (Baton Rouge), Accension (Baton Rouge), Livingston (Baton Rouge), Orleans (New Orleans), St Charles (New Orleans), St Bernard (New Orleans), St Tammany (New Orleans), St John the Baptist (New Orleans), Jefferson (New Orleans).

Tennessee: Shelby (Memphis), DeSota (Memphis), Tipton (Memphis).

Demographic Characteristics

Since 1970, population in the 43 *Central* Delta counties has been relatively stable, showing a slight increase over the 1970-80 period, but falling to 1,047,300 in 1986 (estimated), for a 16-year decline of 1.2 % (Table 1). These statistics suggest that for the *Central* Delta, the massive outmigration, long characteristic of this region (Crecink and Steptoe), has mitigated. When compared to both the metro and nonmetro areas in the more broadly defined Delta, it is evident that population patterns in the *Central* Delta differ significantly. The *Fringe* Delta and Metropolitan Delta counties experienced population increases of 17.2% and 24.7%, respectively, resulting in an *All* Delta population growth of 17.9%. Hence, the overall Delta growth rate differs markedly from the 1.2% decrease for the *Central* Delta.

The nonwhite percentage share of the *Central* Delta's population declined from 1970 to 1980 (37.3% to 34.7%). Similarly, the *Fringe* Delta nonwhite share of the population declined from 23.4% in 1970 to 21.1% in 1980 (Table 1). The decline in the *Central* Delta can be attributed to an actual nonwhite population decrease (6.6%), while the declining percentage share in the *Fringe* Delta was due to a slower rate of growth (2.3%) for nonwhites relative to the total population (13.4%). Like the *Central* Delta, the *Metropolitan* Delta's nonwhite share of the population was approximately one-third of the total in 1980, but in contrast to the *Central* Delta, the percentage share of nonwhites in the metropolitan areas is increasing. Overall, the nonwhite share of the Delta as a whole was significantly greater than the total seven-state area in 1980 (28.6% vs. 16.9%).

The elderly – those aged 65 and over – are becoming a growing segment of the Mississippi River Delta counties, with the *All* Delta areas increasing from 10.3% in 1970 to 11.6% in 1980, a figure comparable to the seven-state averages of 10.2% and 11.4%, respectively (Table 1). The percentages of elderly in the *Central* Delta and *Fringe* Delta sub-regions were noticeably higher in 1980, 13.3% and 14.2%, than the *All* Delta average, which is lowered by the relatively low percentage of elderly residing in the metro areas. The high percentage of elderly in the nonmetro Delta counties is characteristic of an area with emigration of the younger more mobile individuals and is not unlike other rural regions of the U.S.

Selected indicators of well-being for the Mississippi River Delta are presented in Table 2. The overriding characteristic in these data is the poverty rate for the nonmetro *Central* Delta compared to the rest of the Delta. In 1980, 29.7% of the population in the *Central* Delta was below the poverty threshold, compared to 21.3, 17.1, and 20.4% for the *Fringe*, *All Metropolitan*, and the *All* Delta, respectively (Table 2). Relative to other parts of the Delta, the percentage

Table 1. Selected demographic characteristics of Mississippi River Delta counties and states, 1986, 1980, and 1970.

	Nonmetro Delta Counties			Metropolitan Delta Counties				
Selected Variables	Central N=43	Fringe N=134	All N=177	New Orleans-Memphis N=10	Others N=14	All N=24	All Delta Counties N=201	Delta States N=653
Population (thousands)								
1986 estimate	1,047.3	3,083.2	4,130.5	2,294.0	1,818.8	4,112.8	8,243.3	34,649.0
1980	1,064.6	2,984.7	4,049.3	2,169.7	1,695.9	3,865.6	7,914.9	33,608.1
1970	1,060.5	2,631.0	3,691.5	1,933.9	1,364.2	3,298.1	6,989.7	30,722.1
Average county population (thousands)								
1986	24.4	23.4	23.6	229.4	129.9	171.4	41.4	53.1
1980	24.8	22.6	23.1	217.0	121.1	161.1	39.8	51.5
1970	24.7	19.9	21.1	193.4	97.4	137.4	35.1	47.0
Population change (%)								
1980-86	–1.6	3.3	2.0	5.7	7.2	6.4	4.1	3.1
1970-80	0.4	13.4	9.7	12.2	24.3	17.2	13.2	9.4
1970-86	–1.2	17.2	11.9	18.6	33.3	24.7	17.9	12.8
Nonwhite population (thousands)								
1980	369.4	629.8	1,000.2	772.4	491.8	1,264.1	2,263.7	5,679.8
1970	395.6	615.7	1,011.5	653.7	386.1	1,038.9	2,201.7	5,038.4
Nonwhite population (%)								
1980	34.7	21.1	24.7	35.6	29.0	32.7	28.6	16.9
1970	37.3	23.4	27.4	33.8	28.3	31.5	29.4	16.4
Population aged 65 and older (%)								
1980	13.3	14.2	14.0	9.2	9.1	9.2	11.6	11.4
1970	11.3	12.5	12.2	8.1	8.2	8.2	10.3	10.2

Source: Bureau of the Census, U.S. Department of Commerce, Censuses of Population, 1970 and 1980.

share of those below the proverty threshold in the 43 *Central* Delta counties showed the greatest improvement (11.8%) from 1970 to 1980.

Infant mortality rates are also sensitive indicators of economic well-being. For the *Central* Delta, the 1982-84 infant mortality rate was 15.8 per 1,000 live births compared to 13.3 for the *All* Delta and 12.3 for the Delta states as a whole (Table 2). A further breakdown into white and nonwhite components shows that white infant mortality rates were lower initially and have improved more than nonwhite rates. It is noteworthy to point out that over the 1969-71 to 1982-84 period, both nonwhite and white infant mortality rates in the *All* Delta showed greater improvement (42.1% decrease) than the overall Delta states (35.9% decrease).

Education levels in the Delta counties, while improving, continue to lag behind the state averages (Table 2). In 1980, 48.2% of the population 25 or older had completed at least a high school education in the "*All*" nonmetro Delta counties, compared to 60.5% for the seven-state area. Metropolitan areas in the Delta had rates comparable to, and in fact exceeded, the total seven-state area rate in 1980 (64.5% versus 60.5%).

Another indicator of well-being is the percentage of households with a female head. Overall, 16.0% of the Delta's households were headed by females in 1980, up from 12.9% in 1970, representing an increase of 24% (Table 2).

Economic Structure

Personal Income Components

Personal income by place of residence is a broad measure of income including earnings as wages, salaries, and profits as well as dividends-interest-rents and transfer payments (U.S. Department of Commerce). Transfer payments–payments received for which no services are currently being rendered–consist primarily of social security, medicare, and income assistance. Personal income components for the Mississippi River Delta areas for two periods, 1969-71 and 1982-84, are presented in Table 3.

Table 2. Indicators of well-being for Mississippi River Delta counties and states for selected time periods.

	Nonmetro Delta Counties			Metropolitan Delta Counties				
Selected Variables	Central	Fringe	All	New Orleans-Memphis	Others	All	All Delta Counties	Delta States
Population below poverty threshold (%)								
1980	29.7	21.3	23.5	18.1	15.8	17.1	20.4	14.7
1970	41.5	31.5	34.4	21.0	21.9	21.4	28.2	18.0
Infant mortality rate*								
1982-84	15.8	12.8	13.3	13.0	12.0	12.5	13.3	12.3
1976-78	20.1	16.9	17.4	15.4	15.5	15.4	17.3	14.5
1969-71	28.8	23.2	24.3	20.8	21.8	21.3	24.4	19.3
Change 1969-71 to 1982-84 (%)	–45.1	–44.8	–45.3	–37.5	–45.0	–41.3	–45.5	–36.3
White infant mortality rate								
1982-84	9.3	9.4	9.4	8.8	8.7	8.7	9.3	10.4
1976-78	13.0	12.9	12.9	12.5	11.7	12.1	12.7	12.0
1969-71	19.5	18.5	18.7	16.9	17.6	17.2	18.7	16.8
Change 1969-71 to 1982-84 (%)	–52.3	–49.2	–49.7	–47.9	–50.6	–49.4	–50.3	–38.1
Non-white infant mortality rate								
1982-84	22.1	18.4	19.1	19.6	17.0	18.2	19.1	18.6
1976-78	27.6	23.3	24.2	19.9	21.2	20.6	24.1	23.0
1969-71	38.1	31.4	33.0	27.5	29.1	28.3	33.1	29.0
Change 1969-71 to 1982-84 (%)	–42.0	–41.4	–42.1	–28.7	–41.6	–35.7	–42.3	–35.9
Population 25+ who completed high school or more (%)								
1980	44.3	49.5	48.2	63.4	65.9	64.5	56.0	60.5
1970	30.2	34.9	33.7	46.8	52.2	49.0	40.7	46.4
Familes with female household head (%)								
1980	16.8	12.8	13.8	20.1	16.3	18.4	16.0	14.1
1970	13.8	11.1	11.8	15.2	12.7	14.2	12.9	11.2

*Number of deaths for infants less than 1 year old per 1,000 live births.

Source: Bureau of the Census, U.S. Department of Commerce, Census of Population, 1970 and 1980; and Area Resources File, provided by Howard Stambler, Bureau of Health Professions, Health Resources and Services Administration, U.S. Department of Health and Human Services.

Specific personal income components included: industry; services; trade; finance-insurance-real estate (FIRE) and transportation-communications-utilities (TCU); government; capital; and transfer payments.

Industry, as defined in Table 3, contributes to 26.6% of personal income for the *All* nonmetro Delta compared to 22.7% for the total seven-state area in 1984-86. While industry was the single largest component of personal income for the nonmetro Delta overall, its share of personal income declined significantly over the two time periods (34.5% in 1969-71 to 25.6% in 1982-84). Including the metropolitan counties, which had a significantly smaller portion of personal income from industry (18.2% versus 25.6%), lowers the *All* Delta average to 20.6%. Similarly, the metro influence distorts all the personal income components if it is included in the Delta calculations.

Over the two time periods, services, FIRE and TCU, trade, and government showed relatively small changes for the Delta, but, capital and transfer payments increased over the earlier time period. In fact, the transfer payments component exceeded all personal income components with the exception of industry for the nonmetro Delta (Table 3).

Industrial Base Components

The industrial base (comprised of the two industry rows in Table 3) was further disaggregated for the 1969-71 and 1984-86 time periods (Table 4). These figures show that the industrial base composition of the Delta sub-groupings differs considerably. Agriculture is defined to include earned income from farming, income from agricultural services, and income from two components of manufacturing, food and kindred products and textile mill products. It is the largest industry in the *Central* Delta, accounting for 39.6% of the total 1984-86 industrial base, compared to only 15.7% for the *All* Delta counties. Following national trends, the percentage share for agriculture dropped considerably over the two periods.

The "other" category, which includes 13 of the 22 manufacturing sector components not otherwise included, plus fisheries and "other" from the "agricultural services-forestry-fisheries-other" grouping, was the second largest component of the 1984-86 industrial base for all sub-categories considered.

The natural resource components (agriculture, expanded forestry, and mining) accounted for 37.5% of the *All* Delta industrial base in 1984-86.

Table 3. Components of personal income for Mississippi River Delta counties and states, 1969-71 and 1984-86.

Components Personal Income	Year	Nonmetro Delta Counties			Metropolitan Delta Counties			All Delta Counties	Delta States
		Central	Fringe	All	New Orleans-Memphis	Others	All		
		(percent of total personal income)							
Industry[a]	1984-86	24.7	25.9	25.6	18.5	18.0	18.2	20.6	22.7
	1969-71	35.8	34.0	34.5	28.0	25.1	26.5	28.4	31.1
Services	1984-86	9.5	9.8	9.7	15.8	15.2	15.5	13.6	14.3
	1969-71	8.4	9.2	9.0	11.9	12.5	12.2	11.3	11.5
Trade[b]	1984-86	10.1	9.1	9.3	16.0	12.6	14.2	11.7	11.4
	1969-71	12.5	12.1	12.2	18.0	14.3	16.0	14.3	13.8
Fire and TCU[c]	1984-86	6.3	6.2	6.2	12.0	11.4	11.7	9.6	9.8
	1969-71	6.4	6.7	6.6	10.5	11.0	10.8	9.8	10.0
Government	1984-86	11.0	10.9	10.9	10.2	15.4	12.8	12.3	10.7
	1969-71	11.5	12.3	12.1	12.5	17.2	14.7	13.7	12.0
Capital[d]	1984-86	15.2	16.1	15.9	13.1	13.6	13.3	14.8	16.5
	1969-71	9.7	9.7	9.7	9.5	10.6	10.0	10.4	12.1
Transfer payments[e]	1984-86	22.9	22.1	22.3	14.5	13.9	14.2	17.1	14.4
	1969-71	15.5	16.0	15.8	9.3	9.8	9.6	12.1	9.7

[a] Industry includes earned income by place of residence from agriculture, expanded forestry, mining, electrical equipment manufacturing, construction, fabricated metal manufacturing, machinery, and other items mainly the balance of the maufacturing sector. Agriculture includes earned income from farming, agricultural services, and two components of the maufacturing sector – food and kindred products, and textile mill products. Expanded forestry is composed of earned income from forestry and two components of the manufacturing sector – lumber and wood products, and paper and allied products.

[b] Includes wholesale and retail trade categories.

[c] Finance-insurance-real estate (FIRE), and transportation-communications-utilities (TCU).

[d] Includes dividends, interest, and rents.

[e] Transfer payments consist of income people receive for which no services are currently rendered. Key items are payments for social security, medicare, and low income assistance.

Source: Bureau of Economic Analysis, U.S. Department of Commerce, Unpublished Employment and Income Computer Tapes for 1969-86.

Expanded forestry is operationally defined to include forestry and two components of the manufacturing sector: lumber and wood products, and paper and allied products. For the same time period, these three industry categories constituted a larger share (52.6%) of the *Central* Delta's industrial base, indicating a heavy dependence upon natural resource-based industries. Hence, development strategies for the Delta as a whole need to reflect inherent differences in reliance upon natural resource-based industries.

Goods-Producing Sectors

Much has been written of the emerging services-producing sectors of the U.S. economy. The rural economy has been particularly hard hit by the transition to the "services economy." Brown and Deavers state that industrial restructuring has altered the economic basis of life in most rural communities, thereby affecting the economic well-being of rural residents.

Figures for the *All* Delta counties reflect the national trend toward the services sector as shown by the declining percentage of earned income attributed to the goods-producing sectors over the 1969 to 1986 period – 37.4% in 1969 and 29.3% in 1986 (Table 5). Earned income, by place of work, is comprised of wages, salaries, and profits from these sectors: farming, agricultural services-forestry-other, manufacturing, mining, construction, transportation-communications-utilities, wholesale and retail trade, finance-insurance-real estate, services, and government. Earned income figures show that the importance of the goods producing sector in the total seven-state area is similar to that sector in the *All* Delta region. However, the goods-producing sector constitutes a significantly greater portion of the predominantly rural *Central* and *Fringe* Delta economies, 36.6 and 40.4% in 1986, respectively. All the individual regions were similar in that this sector represented a shrinking proportion of earned income.

Table 4. Components of the industrial bases of Mississippi Delta counties and states, 1969-71 and 1984-86.

Components Industrial base by industry[a]	Year	Nonmetro Delta Counties			Metropolitan Delta Counties			All Delta Counties	Delta States
		Central	Fringe	All	New Orleans-Memphis	Others	All		
		(percent of industrial base earned income)							
Agriculture	1984-86	39.6	16.3	21.8	10.3	9.3	9.8	15.7	13.9
	1969-71	52.9	26.5	34.1	15.3	14.8	15.1	24.8	17.8
Expanded forestry	1984-86	5.5	13.9	11.9	6.4	8.2	7.3	9.3	4.8
	1969-71	5.8	14.2	11.8	7.8	9.1	8.4	9.7	4.4
Non-energy mining[b]	1984-86	6.4	5.5	5.7	3.1	3.7	3.4	4.7	6.2
	1969-71	1.9	5.7	4.6	5.8	4.2	5.0	4.8	7.6
Energy mining[c]	1984-86	1.1	6.8	5.4	5.7	3.4	4.5	7.8	6.0
	1969-71	0.7	4.2	3.2	6.1	1.7	3.9	4.9	3.0
Electrical Equipment[d]	1984-86	6.0	4.4	4.8	2.0	5.9	4.0	4.2	7.3
	1969-71	4.4	3.7	3.9	3.0	3.7	3.4	3.4	7.6
Construction	1984-86	11.8	17.4	16.1	30.1	32.4	31.3	22.7	18.7
	1969-71	12.0	15.1	14.2	21.3	30.4	25.8	20.1	16.8
Fabricated metal[d]	1984-86	5.1	4.4	4.5	5.2	4.2	4.7	4.2	6.0
	1969-71	3.4	1.7	2.2	4.7	3.3	4.0	2.8	6.1
Machinery[d]	1984-86	4.8	3.7	3.9	4.9	4.0	4.4	3.9	7.9
	1969-71	2.1	2.2	2.2	5.6	1.7	3.7	2.7	8.6
Other[e]	1984-86	19.7	27.6	25.8	32.3	28.9	30.6	27.5	29.3
	1969-71	16.8	26.6	23.8	30.4	31.1	30.8	26.7	28.2

[a] Industrial base is defined to include earned income by place of residence from agriculture, expanded forestry, mining, electrical equipment manufacturing, construction, fabricated metal manufacturing, machinery manufacturing, and other items – mainly the balance of the manufacturing sector. Agriculture includes earned income from farming, agricultural services, and two components of the manufacturing sector – food and kindred products, and textile mill products. Expanded forestry is composed of earned income farm forestry, and two components of the manufacturing sector – lumber and wood products, and paper and allied products.

[b] Nonenergy mining is composed of metal mining, nonmetal minerals except fuel mining, plus two components of the manufacturing sector – (1) stone, clay and glass products, and (2) primary metal industries.

[c] Energy mining includes anthractie mining, bituminous and lignite mining, oil and gas extraction.

[d] Component selected from the manufacturing sector.

[e] Other is composed of 13 of the 22 components of the manufacturing sector, plus fisheries and "other" from the "agricultural services-forestry-fisheries-other" grouping.

Source: Bureau of Economic Analysis, U.S. Department of Commerce, Unpublished Employment and Income Computer Tapes for 1969-86.

The percentage share of earned income attributable to manufacturing for the Delta supports the hypothesis that "rural" areas are lagging behind in making the transition to a services economy. In 1969, manufacturing accounted for a 28.8% share of the goods-producing component for the total seven-state area, exceeding the *All* Delta counties average of 21.4%. By 1986 the respective percentages had dropped to 22% and 17.9%. The *Central* Delta, however had a growth in manufacturing income over the same time period, implying that the more rural sections of the Delta are still attracting manufactur-

Table 5. Economic structure of Mississippi River Delta counties and states, 1969, 1977, and 1986.

	Nonmetro Delta Counties			Metropolitan Delta Counties				
Earnings by Industry	**Central**	**Fringe**	**All**	**New Orleans-Memphis**	**Others**	**All**	**All Delta Counties**	**Delta States**
	(percent)							
GOODS-PRODUCING[a]								
1986	36.6	40.4	39.5	24.2	24.3	24.3	29.3	32.3
1977	48.9	46.3	47.0	32.2	31.6	31.9	36.7	39.1
1969	46.6	46.0	46.2	35.1	33.0	34.0	37.4	41.0
Manufacturing								
1986	22.9	26.4	25.6	14.9	14.5	14.7	17.9	22.0
1977	19.1	26.8	24.7	20.6	18.0	19.2	20.1	26.2
1969	20.0	26.5	24.7	24.1	19.2	21.6	21.4	28.8
Farm								
1986	6.6	3.9	4.5	0.4	0.6	0.5	1.9	1.7
1977	21.9	6.9	11.0	0.8	1.6	1.2	5.1	3.3
1969	18.2	8.5	11.1	1.0	2.1	1.6	5.3	3.6
Agricultural services, forestry, and fisheries								
1986	1.5	0.6	0.8	0.4	0.3	0.3	0.5	0.4
1977	1.5	0.8	1.0	0.4	0.4	0.4	0.6	0.4
1969	1.3	0.8	0.9	0.3	0.3	0.3	0.5	0.4
Construction								
1986	5.1	6.4	6.1	7.3	8.0	7.7	6.6	6.2
1977	5.8	8.3	7.6	8.9	10.6	9.8	8.5	6.9
1969	6.4	7.1	6.9	7.2	10.5	8.9	7.7	6.8
Mining								
1986	0.4	3.1	2.4	1.2	0.9	1.0	2.4	1.9
1977	0.6	3.5	2.7	1.5	0.9	1.2	2.4	2.3
1969	0.6	3.2	2.5	2.5	0.8	1.6	2.4	1.4
SERVICES-PRODUCING[a]								
1986	63.4	59.6	60.5	75.8	75.7	75.7	70.7	67.7
1977	51.1	53.7	53.0	67.8	68.4	68.1	63.3	60.9
1969	53.4	54.0	53.8	64.9	67.0	66.0	62.6	59.0
Wholesale and retail trade								
1986	17.1	14.7	15.3	21.9	17.4	19.5	17.4	16.7
1977	17.0	16.1	16.3	22.3	18.1	20.1	18.5	17.5
1967	17.6	16.4	16.7	22.1	18.1	20.0	18.7	17.8
Government								
1986	18.6	18.0	18.1	14.7	20.2	17.5	17.6	14.7
1977	14.1	16.0	15.4	15.4	19.2	17.4	16.3	14.2
1969	15.2	16.1	15.8	16.3	19.6	18.0	16.6	14.0
Personal and business services								
1986	16.8	16.7	16.7	22.1	21.8	21.9	21.0	21.7
1977	10.8	12.0	11.7	16.0	16.8	16.4	15.1	15.7
1969	11.7	12.5	12.3	14.1	15.6	14.9	14.6	14.5
Transportation, communications, public utilities								
1986	7.3	7.0	7.0	10.4	8.4	9.4	8.8	7.9
1977	6.1	6.5	6.4	9.2	7.9	8.5	8.4	8.0
1969	5.9	6.0	6.0	8.1	7.6	7.8	8.0	7.6
Finance, insurance, and real estate								
1986	3.6	3.3	3.4	6.7	7.9	7.3	5.9	6.7
1977	3.1	3.2	3.2	4.9	6.5	5.8	5.0	5.5
1969	3.0	2.9	2.9	4.4	6.1	5.3	4.7	5.1

[a] Percentages for goods producing and services producing sectors sum to 100 except for rounding errors.

Source: Bureau of Economic Analysis, U.S. Department of Commerce Unpublished Employment and Income Computer Tapes for 1969-86.

ing industries. Depending upon the nature of this manufacturing growth, future adjustments may be eminent if this region follows the national trend of declining manufacturing employment.

The dependence of the nonmetro Delta on farming (i.e., production agriculture) is reflected in the high proportion of income attributable to that sector relative to the seven-state area in 1986 – 4.5% versus 1.7% (Table 5). While still important, the percentage share has decreased substantially for all regions since 1969, due in part, no doubt, to the financial stresses witnessed in the farm economy in the 1980s (Reimund and Petrulis, 1988; Petrulis et al., 1987).

The agricultural services, forestry, and fisheries sector contributed 0.8% of the earned income for the nonmetro Delta counties in 1986, twice that of the seven-state average. For both economic sectors, the percentages in the *Central* Delta were noticeably greater than those in the *Fringe*, indicating a greater dependency of this part of the Delta on agricultural activity.

Services-Producing Sectors

Overall, the nonmetro Delta counties' earned income from the services-producing sector was 60.5% in 1986, well below the total states' average of 67.7% (Table 5). Earnings from the services-producing sector in the *Central* Delta exceeded that sector's contribution in the *Fringe*, an unexpected finding given the rural nature of these counties.

The wholesale and retail trade, government, and personal and business services sectors, with 1986 earned incomes of 15.3%, 18.1%, and 16.7%, respectively, accounted for the predominant share of the total services income for the nonmetro Delta region. Two sectors, TCU and FIRE, contributed 7.0% and 3.4%, respectively, to earned income in 1986.

The percentage shares within each sector were fairly consistent for the nonmetro Delta regions and the Delta state averages (Table 5). In fact, the 1986 *All* Delta percentage shares for two sectors, wholesale and retail trade and government, were essentially equal to or greater than the states' figures.

Farming and Farm-related Sectors

The preceding discussion treated farming solely as production. This section presents agriculture from a broader perspective, which includes production, agricultural services, and two components of the manufacturing sector, food and kindred products and textile mill products. "Agriculture" as defined in this context captures a portion of the economic activity that occurs beyond the farm gate.

Defined in this manner, earned income from agriculture made up 14.7% of the 1986 total for the nonmetro Delta region, compared to just 11% for all seven states (Table 6). Agriculture in the *Central* Delta, however, accounted for a sizable 18.7% of earned income. Adding the three agriculturally related sectors essentially tripled the share of earned income attributable to agriculture over the amount when farm production alone was considered.

Table 6. Earnings in agriculture and related sectors in Mississippi River Delta counties and states.

	Nonmetro Delta Counties			Metropolitan Delta Counties				
Earnings by Industry	Central	Fringe	All	New Orleans-Memphis	Others	All	All Delta Counties	Delta States
	(percent)							
Agriculture[a]								
1986	18.7	13.5	14.7	8.9	8.7	8.8	10.8	11.0
1977	31.5	15.8	20.1	9.8	9.1	9.4	13.5	11.8
1969	27.6	17.1	19.9	9.6	9.3	9.5	13.4	11.7
Farm								
1986	6.6	3.9	4.5	0.4	0.6	0.5	1.9	1.7
1977	21.9	6.9	11.0	0.8	1.6	1.2	5.1	3.3
1969	18.2	8.5	11.1	1.0	2.1	1.6	5.3	3.6
Agricultural services, food & kindred products, and textile mill products								
1986	12.1	9.6	10.2	8.5	8.1	8.3	8.9	9.3
1977	9.6	8.9	9.1	9.0	7.5	8.2	8.4	8.5
1969	9.4	8.6	8.8	8.6	7.2	7.9	8.1	8.1
Food and kindred products								
1986	4.3	2.5	2.9	2.2	1.6	1.9	2.2	2.5
1977	3.4	2.8	2.9	3.6	2.0	2.8	2.7	2.9
1969	3.5	2.7	2.9	4.0	2.4	3.2	3.0	3.3

[a] Includes earned income in farming, agricultural services, food and kindred products, and textile mill products.

Source: Bureau of Economic Analysis, U.S. Department of Commerce Unpublished Employment and Income Computer Tapes for 1969-86.

Farm Sector Characteristics

The changing structure of the farm sector and its impact on the future of agriculture and the rural communities affected by these changes has long been a subject of concern to social scientists. Several recent reports have emphasized the interrelationships between agriculture and the rural economy (Council for Agricultural Science and Technology; The Task Force on Agriculture and Community Viability; Office of Technology Assessment). This section closely examines changes in farm characteristics in the Mississippi River Delta counties between 1974 and 1982 (Table 7).

The number of farms in the nonmetro Delta region has declined significantly more than the seven-state total (12.8% versus 5.8%) over the 1974 to 1982 period (Table 7). As previously observed, the *Central* Delta's figures differed considerably from the *Fringe* (17.7% versus 11.4%). Not surprisingly, given national trends

Table 7. Farm characteristics of Mississippi River Delta counties and states, 1974 and 1982.

	Non-metro Delta Counties			Metropolitan Delta Counties				
Selected variables	**Central**	**Fringe**	**All**	**New Orleans-Memphis**	**Others**	**All**	**All Delta Counties**	**Delta States**
Farms (Number)								
1982	22,444	83,271	105,715	3,469	8,834	12,303	118,018	527,705
1974	27,258	93,977	121,235	3,675	9,233	12,908	134,143	560,284
Change (%)	-17.7	-11.4	-12.8	-5.8	-4.3	-4.7	-12.0	-5.8
Farm size (Acres)								
1982	659	272	365	351	276	307	358	255
1974	550	256	328	384	271	318	327	242
Change (%)	18	6	11	-9	2	-3	9	5
Average product sales per farm ($)								
1982	124,000	35,000	57,000	57,000	45,000	50,000	56,000	42,000
1974	72,000	22,000	34,000	45,000	39,000	41,000	35,000	26,000
1982 sales from (%)								
Crops	94	49	71	87	60	69	70	57
Livestock	5	32	19	12	25	21	19	32
Poultry	1	11	6	1	13	9	6	9
1974 sales from (%)								
Crops	95	56	75	81	62	67	74	59
Livestock	4	30	17	12	18	16	17	30
Poultry	1	13	7	1	19	14	8	10
1982 farmland in (%)								
Crops	88	61	71	77	67	71	71	70
Pasture	2	16	11	7	13	11	17	14
Woodland	6	25	17	10	18	15	17	17
1974 farmland in (%)								
Crops	84	56	67	73	61	65	67	67
Pasture	4	21	15	12	20	17	15	18
Woodland	7	26	19	10	17	15	18	17
1982 farms with sales (%)								
Less than $10,000	31	63	56	66	69	68	58	55
Less than $40,00	52	83	76	81	82	82	77	78
$40,000 and over	48	17	24	19	18	18	23	22
1974 farms with sales (%)								
Less than $10,000	39	72	65	70	73	72	65	62
Less than $40,000	64	89	84	84	85	85	84	84
$40,000 and over	36	11	16	16	15	15	16	16
Average commodity credit corporation payments per farm ($)								
1982	11,379	1,399	3,518	4,023	2,156	2,682	3,431	2,228
1974	1,444	453	676	786	734	748	683	466
Operators with off-farm employment (%)								
1982	37	58	54	61	60	60	54	55
1978	39	59	55	58	60	59	55	56
1974	39	61	57	61	63	63	57	58
200+ days of off-farm employment (%)								
1982	21	39	35	44	42	42	36	37
1978	22	40	36	42	43	43	37	37
1974	21	41	37	43	46	45	37	38

Source: Bureau of the Census, U.S. Department of Commerce, Censuses of Agriculture, 1974, 1978, 1982.

in farm numbers and size, the drop in farm numbers was essentially offset by an average increase in farm size of 11% in the nonmetro Delta (18% in the *Central* Delta). The large-scale nature of agriculture in the *Central* Delta region is evident from the fact that the 1982 average farm size in that region is more than double that in the *Fringe* and total seven-state area (659 acres versus 272 and 255, respectively) (Table 7). Average product sales per farm closely followed the pattern of farm size.

The distribution of farm sales classes further documents the large-scale nature of farming across the Delta. Almost half (48%) of the farms in the *Central* Delta had sales of more than $40,000 in 1982, compared to just 17% and 22% in the *Fringe* Delta and the seven-state area, respectively. Consistent with the changes in farm size noted, the trend since 1974 has been toward larger farms in terms of sales, evidenced by the fact that the $40,000 and over sales class was the only grouping showing a percentage increase over time. While other factors, increased productivity and increasing product prices for example, may contribute to the increased numbers within a farm sales grouping without increasing farm size, the farm sales data are supportive of increasing farm size.

The large farm operations prevalent in the *Central* Delta resulted in a low percentage (21%) of farm operators reporting off-farm employment of 200 days or more in 1982.

Reflecting the relatively homogenous nature of agriculture across the *Central* Delta, land use was predominantly devoted to crops (88% in 1982). Showing increased diversity, the *Fringe* Delta only had 61% of its acreage devoted to crops. Comparing the percentage sales figures for crops, livestock, and poultry over the 8-year period indicates that the *Central* Delta's specialization in crop production has remained essentially unchanged while the *Fringe* Delta has diversified slightly.

Income

Total personal income per capita for the *All nonmetro* Delta was 72% of the seven-state average in 1986, up from 66% in 1969. The *Central* Delta was 67% of the seven-state average in 1986 compared to 61% in 1969 (Table 8). Overall, the growth rate for the nonmetro Delta counties for the 1969-1986 period has been slightly lower than the rate for the seven-state area. The gap in 1980 median family income between

Table 8. Income of residents of Mississippi River Delta counties and states.

	Non-metro Delta Counties			Metropolitan Delta Counties				
Selected variables	**Central**	**Fringe**	**All**	**New Orleans-Memphis**	**Others**	**All**	**All Delta Counties**	**Delta States**
Total personal income per capita (TPI) ($)								
1986	8,718	9,694	9,446	13,083	12,222	12,646	11,065	13,040
1977	5,035	5 ,065	5,057	6,766	6,418	6,589	5,816	6,839
1969	2,102	2,341	2,272	3,297	3,051	3,173	2,721	3,462
Median family income ($)								
1980	11,885	14,041	13,511	19,293	18,145	18,624	14,128	15,278
1970	4,823	5,692	5,478	8,169	7,343	7,687	5,745	6,450
Increase (%)	146	147	147	136	147	142	146	137
Transfer payments per capita ($)								
1986	2,156	2,187	2,179	1,852	1,854	1,853	2,051	2,021
1977	950	992	980	823	865	844	931	945
1969	306	345	334	244	288	266	310	317
Property income per capita ($)								
1986	1,379	1,575	1,525	1,730	1,680	1,705	1,658	2,146
1977	499	526	518	595	603	599	579	800
1969	212	225	222	315	324	319	284	420
Transfer payments as percent of TPI (%)								
1986	24.7	22.6	23.1	14.2	15.2	14.6	18.5	15.5
1977	18.9	19.6	19.4	12.2	13.5	12.8	16.0	13.8
1969	14.6	14.7	14.7	7.4	9.4	8.4	11.4	9.2
Property income as percent of TPI (%)								
1986	15.8	16.2	16.2	13.2	13.7	13.5	15.0	16.5
1977	9.9	10.4	10.2	8.8	9.4	9.1	10.0	11.7
1969	10.1	9.6	9.8	9.5	10.6	10.1	10.4	12.1

Source: Bureau of the Census, U.S. Department of Commerce, Censuses of Population, 1970 and 80; and Bureau of Economic Analysis, U.S. Department of Commerce, Unpublished Employment and Income Tapes for 1969-86.

the *Central* and *Fringe* Delta and the seven-state area (77 and 88%, respectively) was narrower than that for per capita personal income.

Transfer payments, including social security, medicare, income assistance, and several other sources (Hoppe and Saupe), have been an increasingly important part of income. Transfer payments increased from 14.7% of personal income in 1969 to 23.1% in 1986 in the *nonmetro* Delta (Table 8). While accounting for a larger share of personal income in the Delta, transfer payments to *nonmetro* Delta residents have actually increased less than the seven-state rate over the 1969-1986 period (57% versus 68%).

Comparing the Delta Study Areas

Central Nonmetro Delta

The pattern depicted by the variables considered make this area quite distinctive from the other Delta geographic parts. It was the only area with a population decline (–1.6%, 1980-86). In the context of difficult economic times during the early 1980s in field crop agriculture, manufacturing, and the energy sector, the population decline suggests severe hardships for both those who left and those who stayed. The leavers, while probably younger and better educated than those left behind, faced severe competition for jobs elsewhere. The stayers, who tend to be older and with lower educational attainment, found themselves in states strapped for funds to assist in meeting their basic needs.

Level of living indicators suggest a pattern of severe under-education and deprivation. Almost 30% of the population was in poverty in 1980. Chronic poverty reduces people's ability to obtain medical care in the traditional fee-for-service medical system. This deficiency manifests itself in important ways, especially in high infant mortality rates. The highest infant mortality rate (15.8 deaths per 1,000 live births in 1982-84) occurred in the *Central nonmetro* Delta. For nonwhite infants in 1982-84, the rate was 22.1 in the *Central nonmetro* Delta. This complex interactive group of existing poverty-linked characteristics will resist short-run, piecemeal programmatic efforts to improve conditions.

The economic structure is different from that in the other study areas, owing mainly to more dependence on agriculture and farming. Judged by farm acreage and gross farm sales, the region's farms are large and getting larger. The number of farms dropped sharply between 1974 and 1982. Farm product sales are almost entirely from field crops rather than from vegetables, livestock, poultry or dairy enterprises. Thus, Federal farm subsidies are substantial in behalf of resource owners. Almost half of the *Central nonmetro* Delta's farms can be classified as commercial ($40,000 or more of farm product sales, 1982).

The *Central nonmetro* Delta had the lowest per capita and median family incomes for the dates considered. Transfer payments were almost a fourth of total personal income in 1986, indicating a somewhat aged population. The presence of a large minority population (35% nonwhite, in 1980) in the context of accumulated wealth imbedded in large commercial farms suggests that the low median and per capita incomes may greatly understate the serious problems faced by the large stratum of low-income people. Low levels of education and cash make geographical and occupational mobility unusually difficult.

Fringe Nonmetro Delta

This large upland, rolling hills region is decidedly different from its *Central* counterpart. This predominantly white area experienced substantial population increases in the 1970s and 1980s. Compared to the *Central* Delta region, the *Fringe's* population is older, partly because its scenic land and water forms appeal to retirees.

The level of well-being in the *Fringe* nonmetro Delta is relatively high in key aspects, compared to the *Central* Delta, but not in relation to indicators in the *Metropolitan* Delta counties and the Delta states. For example, almost half of the adult population in 1980 had completed high school compared to 44% in the *Central* Delta and 65% in the *Metropolitan* Delta counties.

The *Fringe nonmetro* Delta's personal income source pattern is quite similar to that existing in the *Central nonmetro* Delta. However, when the industrial base (1984-86) is examined, three important differences appear. First, there is far less dependence on agriculture (16.3% of industrial base earned income versus almost 40%). Second, there is more dependence on expanded forestry (13% versus 5.5%). And third, there is more dependence on the energy mining sector (6.8% versus 1.1%). Its number of farms is large in relation to that of the *Central* Delta region (83,000 versus 22,000 in 1982) and declining. Also, its farms average 40% the acreage of those of the *Central* Delta region.

The *Fringe* Delta farms tend to be diversified with emphases on crops, livestock, and poultry. Almost two-thirds of the *Fringe* area's farms are rural residence in nature with farm product sales of less than $10,000 in 1982. Federal farm subsidies averaged only a tenth of those sent to *Central* Delta farmers, with economic survival more dependent on off-farm employment. Almost 40% of the *Fringe* Delta farmers reported off-farm employment of 200 days or more in 1982.

Average income levels placed the *Fringe* region in the middle of the regions considered. As in the *Central* Delta, there was heavy dependence on transfer payments denoting an older population, including retirees.

Metropolitan Delta Counties

This area's 24 counties had the same population size (4 million in 1986) as the 175 nonmetro Delta counties, but their rate of increase during 1970 to 1986 was much higher. Data suggest a nonelderly population with numbers sufficient to sustain a diverse blend of goods and services, especially the latter.

Indicators of well-being suggest much of the bases for a relatively-prospering metropolitan economy. For example, nearly two of three adults had at least a high school education in 1980. The population stratum classified as being in poverty was relatively low, particularly in the metropolitan group named "others" (excludes New Orleans and Memphis). Not surprisingly, median family income was highest among the study areas.

Economic structure is characterized by emphasis on the service-producing sectors, which generate more than three-fourths of earned income. Also noteworthy is the relatively strong presence of "finance, insurance, and real estate" and "personal and business services" as percentages of 1984-86 earned income. Construction is a powerful element of the metropolitan counties' industrial base compared to the other study areas. The agricultural sector is small, based on earned income percentages, and it is declining. Farms are small in terms of product sales, and off-farm employment of 200 days or more is largest of the areas considered because of non-farm opportunities and urban pressures on farm size and farm operations.

Implications

As presently identified, the Delta is extremely heterogeneous—too much so for development policy purposes. Thus, delineation of more homogeneous subareas is warranted. This need prompted the authors to conduct the analysis based on four residence categories—nonmetropolitan and metropolitan, with the latter being divided into a combination of New Orleans and Memphis and the balance being the smaller metropolitan counties. The nonmetropolitan area was divided into the *Fringe* and *Central* county groups, which became the focus of attention. Policies need to be tailored to address the needs and potentials existing within the regional parts rather than having a more generalized policy set for the entire region. In this section, attention is limited to the *Central nonmetro* Delta.

If policymakers take a "worst-first" approach, then the *Central nonmetro* Delta area deserves national attention. Since it lies mainly within the three states that have long been among the states with the lowest per capita incomes (Arkansas, Louisiana, and Mississippi), **outside** economic intervention is critical. This assertion gains further credence due to the *Central* Delta's heavy reliance on natural resource sectors (especially field crop farming), and the fact that it tends to not contain nor be adjacent to major metropolitan centers. Venus (1989) notes accurately: "The Delta is, and will continue to be, primarily a vast, extremely valuable agricultural area. The agricultural revolution long ago reduced the need for labor to a level far below the area's labor force. Outmigration since the 1950s has helped reduce the excess population, relative to the needs of agriculture, and industrial development has helped provide additional employment, but thousands of people cannot and will not find employment in this region."

It should be noted that the prolonged net outmigration appears to have been selective, leaving an older, less educated residual population. As a result, the national conventional models for delivering education, medical care, job training, transportation, housing, and other basics need to be modified to assist large groups of people who have several poverty-linked characteristics. Conventional delivery systems can sometimes accommodate a few people who have a single handicap, but not multiple problems.

The *Central nonmetro* Delta is faced with two policy sets, or a combination: **(1)** a rural transition policy based on education, non-farm occupational training and other mobility enhancers; and/or **(2)** a rural development policy based on application of new resources to diversify existing economies while supporting traditional sectors (Drabenstott et al., 1987). The flagship of the rural transition policy could be implementation of a new type of magnet school strategically located in the *Central nonmetro* Delta. Colleges of education, together with selected private sector entities, who have strong reputations for being innovative and creative in the human capital realm (especially remedial education and health), could receive Federal support to guide and/or operate the Delta magnet schools. Funding legislation would permit the school systems to respond to multiple poverty-linked traits, and to the educational needs of adults as well as the school-age population. As effective approaches to human capital creation under *Central nonmetro* Delta conditions are discerned, such measures could be recommended and provided to the existing educational establishment.

One focal point of rural development policy directed at existing economies, including traditional sectors, could be coordinated strong support for aquaculture.

Such a policy measure is justified for three reasons. First, the desire by Americans for a wellness-oriented health care system is leading to a secular change in diet (i.e., consumption of white rather than red meats). Mississippi already has the largest acreage of any state in catfish production. Second, vast land and groundwater resources in the *Central nonmetro* Delta have no reasonable use other than aquaculture and traditional field crops. For example, fruits and vegetables have not proven to be viable alternatives because of climatic and/or soil conditions of the *Central nonmetro* Delta. And third, the aquacultural products are processed close to production sites, thereby allowing the value-added steps to increase local income and employment. Coordination is needed to ensure that production of fish is based on appropriate aquacultural biology and related research; that processing facilities are geared concurrently to increasing supplies of fish; development of other fish species as commercially viable options; and marketing research must be an integral part of the entire endeavor. As in the case of broilers, vertical integration could be considered as a mechanism to get the high degree of coordination necessary for success.

Special Delta schools and aquaculture are types of societal investments that could pay huge dividends. These two measures could at least start the *Central nonmetro* Delta region's economy on a far better path.

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966

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Influence of RICE Production on Subsequent COTTON Growth and Yield

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Influence of Rice Production on Subsequent Cotton Growth and Yield

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Influence of Rice Production on Subsequent Cotton Growth and Yield

Introduction

Since the 1700's, measuring the response of crops and soils to various cropping systems or sequences has been of interest to many researchers (32). The first consideration in crop rotation is yield maintenance (11). Secondary to this is pest control, prevention of soil erosion, and maintenance of soil nutrient status.

The benefits of crop rotation on cotton yields have varied. Sturkie (29) reported that average yields of cotton and corn were increased by rotating when compared to continuous cropping systems. In another study, continuous cotton yielded 17 pounds per acre (lb/A) less than the highest yielding rotation (3). In other rotational studies throughout the cotton belt, results have varied (2, 13, 14, 15, 27). Although yield is a primary consideration, crop rotation is usually practiced to prevent yield decline of the primary crop instead of to enhance yield.

While yield considerations are paramount to the utilization of crop rotations with cotton, rotations have been more successful in benefiting pest control. Crop rotations have been successful in reducing incidence of diseases, nematodes, and weeds (1, 7, 9, 17, 26). Dale and Chandler (8) effectively controlled johnsongrass by growing corn in rotation with cotton. In the southern United States, rice is commonly rotated with soybeans to reduce grass infestation in subsequent rice crops. Herbicide crop rotation studies have been conducted to maximize weed control while reducing or varying herbicide input (9, 24).

The influence of crop rotations on soil productivity has been reported by many researchers (10, 16, 21, 23, 30, 31). Brawand and Hossner (4) studied the nutrient status of sorghum leaves and grain as affected by rotations. Spurgeon and Grissom (28) reported that organic matter content of soils increased when a sod crop was used in different cropping systems. However, this was the only significant change for several rotation sequences. Crop rotation sequences have also been shown to alter enzymatic events in the soil, which may or may not be beneficial (25).

Recently, market instability of various commodities has precipitated the need for diversification of income, which can be considered an additional benefit of crop rotation. By increasing the number of commodities produced per farm unit, producers can offset some of the risk associated with producing one particular commodity. Also, different cultural practices needed at different times for various crops provide for a more even distribution of labor. Historically, in the Mississippi Delta, cotton has been grown continuously on soils with less than 1% organic matter. Soil organic matter plays a major role in the chemical, microbiological, and physical aspects of soil fertility. Continuous cotton produces little residue and as a result, depletion of soil organic matter is possible.

Soybean-cotton and soybean-rice rotations have been reported (2, 15, 19), but there have been only limited studies on rice-cotton cropping systems (18, 20) – and those were in India. The study summarized in this bulletin was conducted to examine the influence of rice on subsequent cotton yield, growth, and soil parameters.

Materials and Methods

This experiment was initiated in 1984 at the Mississippi Agricultural and Forestry Experiment Station Delta Branch Station at Stoneville on a mixed Bosket (Mollic hapludalf) and Beulah (Typic dystrochepts) very fine sandy loam that had been in cotton for approximately 10 years. The six rotations selected for evaluation were: (1) continuous cotton; (2) continuous rice; (3) 1 year rice:1 year cotton; (4) 1 year rice:2 years cotton; (5) 2 years rice:2 years cotton; and (6) 1 year rice:3 years cotton. Treatments were 60 feet wide by 130 feet long replicated four times.

General recommended crop production practices were utilized for each crop in an effort to obtain maximum yields. Plots planted to cotton were subsoiled to a depth of 14 to 16 inches in the late fall or winter each year. Cotton (cv. DES 422) was hill-drop planted to 40-inch rows during the last 2 weeks of April each year at a seeding rate of 19 lb/A. Anhydrous ammonia was applied prior to planting at the rate of 100 lb/A of nitrogen (N) and was the only fertilizer used in cotton. Weed control was maintained with applications of trifluralin applied preplant incorporated, followed by fluometuron or norflurazon applied preemergence at planting. Cultivation and post-directed applications of dinoseb or fluometuron + MSMA were used to control escaped weeds. Cotton was machine-harvested each year and seed cotton weight was recorded.

Rice (cv. 'Newbonnet') was drill-seeded in mid to late April each year at a seeding rate of 90 lb/A. When necessary, rice was flood-irrigated to obtain a stand.

A 2- to 4-inch permanent flood was established in late May or early June when rice was 6 to 8 inches tall. Nitrogen, at a rate of 135 lb/A, was applied as urea immediately prior to flooding. Weeds were controlled with tank-mix applications of propanil + thiobencarb or bifenox applied postemergence prior to flooding.

In March 1984, 1986, and 1987, and in April 1985, soil samples to depths of 0 to 6 inches and 6 to 12 inches were taken from each plot and analyses conducted by the Mississippi Cooperative Extension Service Soil Testing Laboratory at Mississippi State University. Results were tabulated and analyzed to examine the influence of each rotation on soil test values.

During the third and fourth years of the study, soil compaction, and heights and populations of cotton were measured in each cotton plot approximately 6 weeks after planting. Data for plant populations were taken within each plot from four random locations 10 row-feet in length. Main stem height of 10 plants was measured within each of these 10-foot sections for plant height determination. Soil compaction or cone index was determined from 10 penetrometer readings taken within each plot.

Net returns were calculated for each treatment to determine profitability. Calculations were derived from actual yields from each plot. Cotton revenue was based on $0.57/lb of lint, which was the 5-year average reported in 1988 (6). Lint percentage was assumed to be 38%. Seed and trash percentages were 50% and 12%, respectively. A price of $0.04/lb was added to revenue for cottonseed. Total specified expenses for cotton were $405.73/A. Rice revenue was based on a price of $3.42/bushel. Total specified expenses for rice were $370.47/A. In 1986 and 1987, total specified expenses were $388.97/A for the continuous rice plots due to the necessity of an additional propanil application for weed control.

All data were subjected to analysis of variance for an RCB and differences were significant at the 5% probability level according to Fisher's Protected Least Significant Difference (LSD) Test. Where appropriate, sub-sample error was included in the analysis.

Results and Discussion

Cotton establishment and growth

Cotton populations in 1986 were similar for all production systems evaluated (Table 1). However, in 1987 cotton populations were significantly higher in the 1:1 system than in continuous cotton. This suggests a possible reduction in disease incidence for this system. However, disease incidence was not reported and did not appear prevalent during the 1987 season. In a 1:1 system, adjustment in plant populations may need to be considered.

Table 1. Influence of a rice-cotton rotation on various cotton or soil parameters after 4 years. Delta Branch Experiment Station, Stoneville, MS.

Treatment description	Cotton data					
	Stand counts		Crop height		Cone index	
	1986	1987	1986	1987	1986	1987
	(plants/acre)		--------(in)--------		------(psi)------	
Continuous cotton	65,350	57,500	11	14	720	950
1:1 Rice-cotton	–	64,040	–	12	–	940
1:2 Rice-cotton	66,660	–	11	–	940	
2:2 Rice-cotton	70,580	62,740	9	15	1,050	920
1:3 Rice-cotton	69,270	58,820	11	13	770	930
LSD (5%)[1]	6,540	5,230	1	1	220	70
C.V. (%)	11.5	12.7	13.6	12.9	25.5	17.0

[1] For comparison of any two means within a column.

Cotton height was reduced in 1986 following 2 years of rice compared to continuous cotton (Table 1). In 1987, cotton height was reduced following 1 year of rice as compared to the continuous cotton treatment. Control of crop height is desirable throughout much of the irrigated cotton belt. However, implementation of a rotation system involving rice to control crop height seems less reliable than conventional methods, such as applications of growth regulators.

Reductions in crop height in 1986 can be explained in part by soil compaction, which was greater following 2 years of rice than in any other system evaluated in 1986 (Table 1). This increase in compaction could conceivably adjust crop growth and establishment. In 1987, soil compaction did not seem to be influenced by any rotation system. Soil compaction following 2 years of rice may have increased due to the cementing action of water.

Table 2. Influence of a rice-cotton rotation on crop yield for 4 years at the Delta Branch Experiment Station, Stoneville, MS.

Treatment description	Crop yields[1]		
	1985	1986	1987
	---------(lb/A)---------		
Continuous cotton	2,376	1,556	2,351
Continuous rice	(6,963)	(5,972)	(5,254)
1:1 Rice-cotton	2,480	(5,672)	2,007
1:2 Rice-cotton	2,565	1,507	(5,928)
2:2 Rice-cotton	(7,111)	1,961	2,242
1:3 Rice-cotton	2,499	1,307	2,084
LSD (5%)[2]			
cotton	491	714	274
rice	1,912	1,609	886
C.V. (%)			
cotton	12.4	28.2	12.2
rice	12.1	12.3	7.1

[1] Rice yields are shown in parentheses. Cotton yields are for seed cotton.

[2] For comparison of any two means within a column or crop.

Seed cotton yield

In 1985 and 1986, seed cotton yields (Table 2) were not influenced by any rotation system evaluated when compared to continuous cotton. However, there was a trend for higher yields following 2 years of rice. This numerical increase may be largely attributed to the fact that subsoil moisture was more adequate in plots that had 2 previous years of flooded rice. In 1987, second and third year cotton crops following rice were similar. In the 1:1 system, seed cotton yields were lower than in the continuous cotton plots. This may be due to the higher plant population (approximately 64,000/A) in these plots. Bridge et al. (5) reported gradual yield declines from plant populations greater than 48,000 plants/A. However, this may not apply to the earlier, faster fruiting varieties such as the one used in this study. They also reported that hill-drop planted cotton was more sensitive to higher populations than drill-planted cotton.

Soil nutrient status

Percent organic matter at either depth sampled was not affected by any system evaluated (Table 3). Soil pH at the 6- to 12-inch depth was not affected by any system evaluated. In 1987, soil pH for the continuous cotton system was statistically higher than any system except the 1:3 rice-cotton rotation. Earlier reports have indicated that the rotation receiving the greatest amount of nitrogen fertilizer had lower pH values (14). In this study, rice received 35 pounds per year more nitrogen than cotton. Phosphorus and potassium remained relatively unchanged at either depth for all systems evaluated (Table 4). By 1987, calcium levels at 0-6 inches were lower in continuous rice plots and plots with the 1:1 system.

Differences in magnesium, zinc, and sulphur did not appear to be due to the rotational scheme (Table 5). For example, in 1987, the 1:1 system seemed to deplete magnesium more than other systems. However, the magnesium level was found to be lower in these plots at the beginning of the study. When comparisons were made to continuous cotton, differences in these elements were not apparent.

Changes in soil nutrient status for this study were minor and support earlier findings (15, 22, 28). These types of changes usually require longer periods than reported here and usually involve those crops which provide residual nitrogen such as legumes (12). Both cotton and rice require additional inputs of nitrogen to achieve maximum yield. The soil type used in this study tested high or very high for all available nutrients other than nitrogen. Thus, it appears that any change in the soil nutrient status would be in addition to that already present and of no benefit to the crop. Changes in soil nutrient status, if definable for these systems, would be more important on soil

Table 3. Influence of a 4-year rice-cotton rotation on percent organic matter and soil pH. Delta Branch Experiment Station, Stoneville, MS.

Treatment description	Soil test analysis at 0 to 6 inches[1]							
	% Organic matter				Soil pH			
	1984	1985	1986	1987	1984	1985	1986	1987
	(%)							
Continuous cotton	0.78	0.93	0.86	0.65	6.7	6.2	6.1	7.0
Continuous rice	0.73	0.90	0.84	0.68	6.5	6.3	6.2	6.7
1:1 Rice-cotton	0.71	0.96	0.86	0.70	6.6	6.1	6.2	6.7
1:2 Rice-cotton	0.76	1.01	0.85	0.74	6.6	6.3	6.2	6.7
2:2 Rice-cotton	0.86	0.99	0.90	0.78	6.7	6.4	6.2	6.6
1:3 Rice-cotton	0.76	1.00	0.93	0.81	6.6	6.1	6.3	6.8
LSD (5%)[2]	0.13	0.12	0.1	0.1	0.2	0.5	0.3	0.3
C.V. (%)	11.5	8.1	7.4	12.5	2.9	5.0	3.5	2.5
	Soil test analysis at 6 to 12 inches							
Continuous cotton	0.69	0.79	0.66	0.52	6.6	6.2	6.5	6.7
Continuous rice	0.68	0.73	0.67	0.60	6.5	6.7	6.6	7.1
1:1 Rice-cotton	0.67	0.77	0.52	0.54	6.5	6.3	6.4	7.0
1:2 Rice-cotton	0.66	0.87	0.59	0.63	6.4	6.4	6.4	6.9
2:2 Rice-cotton	0.76	0.83	0.65	0.62	6.8	6.7	6.6	7.0
1:3 Rice-cotton	0.62	0.80	0.49	0.60	6.5	6.3	6.4	6.7
LSD (5%)	0.17	0.13	0.2	0.2	0.4	0.5	0.4	0.4
C.V. (%)	17.0	11.2	20.4	20.0	3.8	5.1	2.8	3.5

[1] As determined by the MCES Soil Testing Laboratory.

[2] For comparison of any two means within a column or sample depth.

Table 4. Influence of a 4-year rice-cotton rotation on phosphorous, potassium, and calcium. Delta Branch Experiment Station, Stoneville, MS.

Treatment description	Soil test analysis at 0 to 6 inches[1]											
	Phosphorous				Potassium				Calcium			
	1984	1984	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987
	(lb/A)											
Continuous cotton	201	215	211	163	341	379	355	330	2,825	3,118	3,025	2,341
Continuous rice	188	190	196	143	331	372	334	238	2,930	2,825	2,686	1,800
1:1 Rice-cotton	189	188	210	155	345	409	366	288	2,695	2,699	2,739	1,808
1:2 Rice-cotton	232	236	226	191	340	436	339	291	3,237	3,466	2,803	2,247
2:2 Rice-cotton	226	222	238	176	392	409	387	298	2,845	3,091	3,057	2,287
1:3 Rice-cotton	212	202	232	175	359	396	343	312	3,026	2,962	3,101	2,421
LSD (5%)[2]	57	44	72	67	102	83	58	94	758	783	289	438
C.V. (%)	18.1	13.9	21.7	18.8	19.3	13.8	10.9	21.2	17.2	17.1	6.6	13.5
	Soil test analysis at 6 to 12 inches											
Continuous cotton	216	252	218	160	287	361	236	173	3,182	4,100	3,546	2,414
Continuous rice	199	227	211	188	289	355	250	201	3,219	3,692	3,618	2,468
1:1 Rice-cotton	206	232	215	192	302	382	256	215	3,221	3,610	3,360	2,365
1:2 Rice-cotton	240	270	280	234	290	392	243	178	3,120	4,329	3,335	2,751
2:2 Rice-cotton	237	285	231	202	334	408	274	214	3,605	4,272	3,495	2,742
1:3 Rice-cotton	226	257	233	181	282	360	212	198	3,507	3,760	3,140	2,560
LSD (5%)[2]	90	80	132	79	101	78	68	68	634	478	350	624
C.V. (%)	27.1	27.1	37.7	27.2	22.5	13.8	18.5	23.0	12.7	8.0	8.7	16.2

[1] As determined by the MCES Soil Testing Laboratory.

[2] For comparison of any two means within a column or sample depth.

Table 5. Influence of a 4-year rice-cotton rotation on magnesium, zinc, and sulphur. Delta Branch Experiment Station, Stoneville, MS.

Treatment description	Soil test analysis at 0 to 6 inches[1]											
	Magnesium				Zinc				Sulphur			
	1984	1984	1986	1987	1984	1985	1986	1987	1984	1985	1986	1987
	(lb/A)											
Continuous cotton	480	454	508	366	4.5	4.7	6.7	2.2	111	133	123	93
Continuous rice	429	436	496	356	3.3	4.9	6.1	2.1	116	128	121	97
1:1 Rice-cotton	429	438	488	272	5.2	4.4	4.5	1.6	102	128	123	100
1:2 Rice-cotton	437	626	536	412	4.2	6.2	6.6	2.1	109	142	122	107
2:2 Rice-cotton	425	486	567	365	3.7	5.4	5.6	2.1	124	145	130	112
1:3 Rice-cotton	528	550	574	395	3.1	4.3	5.0	1.9	109	144	133	116
LSD (5%)[2]	66	136	176	130	3.5	1.8	3.3	0.8	27	17	14	20
C.V. (%)	9.6	18.1	22.1	23.9	58.4	23.3	38.0	25.3	15.9	8.1	7.3	12.6
	Soil test analysis at 6 to 12 inches											
Continuous cotton	578	520	711	406	3.7	5.4	4.0	2.0	99	113	96	74
Continuous rice	569	529	698	571	3.7	4.9	4.9	1.7	98	105	90	85
1:1 Rice-cotton	542	514	862	417	2.5	5.9	3.2	1.5	96	110	74	78
1:2 Rice-cotton	537	563	715	452	3.6	5.6	4.2	2.2	95	125	84	91
2:2 Rice-cotton	531	605	709	492	4.0	6.4	3.9	2.4	109	119	93	87
1:3 Rice-cotton	650	642	908	511	2.1	4.4	2.9	1.5	89	114	71	91
LSD (5%)[2]	104	101	218	258	1.6	2.4	2.3	0.6	25	20	26	26
C.V. (%)	12.2	12.0	18.8	36.0	32.2	29.0	39.6	20.7	17.2	11.4	20.5	20.8

[1] As determined by the MCES Soil Testing Laboratory.

[2] For comparison of any two means within a column or sample depth.

types that require additional inputs of nutrients other than nitrogen.

Net returns

The 4-year average net return per acre was calculated for each rotational scheme. Continuous cotton resulted in $143/A net return (Table 6). Two years of rice followed by 2 years of cotton resulted in net returns of $131/A. The 1:1 system had a 4-year average net return of $114/A. There were no statistical differences in net returns for any system evaluated. However, numerical differences, such as those discussed earlier, favor continuous cotton over a rotational system. This, coupled with the lack of short-term soil benefit, makes it difficult to consider rice as a rotational crop with cotton.

Table 6. Net returns (above specified expenses) to land and management for six rice-cotton rotation systems. Delta Branch Experiment Station, Stoneville, MS.

	Net returns[1]				
Treatment	1984	1985	1986	1987	4 yr-avg.
	($/A)				
Continuous cotton	301	156	–36	150	143
Continuous rice	(116)	(158)	(65)	(10)	88
1:1 Rice-cotton	(145)	181	(61)	69	114
1:2 Rice-cotton	(160)	201	–49	(80)	98
2:2 Rice-cotton	(170)	(170)	58	125	131
1:3 Rice-cotton	(154)	186	–96	87	83
LSD (5%)[2]	84	NS	NS	NS	NS

[1] Returns for rice are shown in parentheses.

[2] For comparison of any two means.

Conclusion

On a short-term basis, rice did not influence seed cotton yields appreciably, nor did it offer any advantages in terms of net profit. In fact, a slight reduction in yield occurred following 1 year of rice in 1987, due apparently to increased plant populations and reduction in height. The appreciable amount of rice straw at the end of the growing season did not improve organic matter as expected. For this soil type, continuous rice seemed to reduce available calcium significantly.

Problems associated with production of rice on the soil type used in this study make it economically infeasible to produce at present. These problems include:

(1) Instability of levee construction due to high sand content.
(2) The need for increased flushings early in the spring to maintain crop uniformity and stand. Flushing was necessary in some cases to alleviate constriction of young plants at the soil line.
(3) Nitrogen rates for rice on this soil type have not been established and will be necessary to more closely optimize yield.
(4) Disease incidence was higher on this soil type than when similar rice varieties were grown on other soil types in adjacent areas.
(5) An increased level of management was required due to fertilization, weed control, and disease problems associated with the soil type used in this study.

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